ANNUAL REPORT

OF THE

SECRETARY OF WAR

FOR

THE YEAR 1891.

IN FIVE VOLUMES.

VOLUME II–IN A

PAR

ANNUAL REPORT

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SECRETARY OF WAR

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VOLUME II—IN SIX PARTS.

PART 6.

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ANNUAL REPORT OF THE MISSISSIPPI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

THE MISSISSIPPI RIVER COMMISSION,
PRESIDENT'S OFFICE,
New York, July 17, 1891.

SIR: The Mississippi River Commission has the honor to submit this its annual report for the fiscal year ending June 30, 1891.

At the date of its last annual report all operations in the field, whether of construction or of survey, were, with some small exceptions, suspended for want of funds. The river and harbor act of September 19, 1890, provided for—

Improving Mississippi River from the Head of the Passes to the mouth of the Ohio River, including salaries, clerical, office, traveling, and miscellaneous expenses of the Mississippi River Commission: Continuing improvement, $3,200,000, which sum shall be expended under the direction of the Secretary of War in accordance with the plans, specifications, and recommendations of the Mississippi River Commission, for the general improvement of the river, for the building of levees, for surveys, including the survey from the Head of the Passes to the headwaters of the river, for the work at the harbors at Hickman, Ky., at New Madrid, Mo., at Helena, Ark., at Greenville, Vicksburg, and Natchez, Miss., at New Orleans, La., at the head of the Atchafalaya and the mouth of the Red River, and at other localities, in such manner, to such extent, and in such proportion as in their opinion shall best promote the interests of commerce and navigation: *Provided*, That the amount expended from such sum for work at the harbors aforesaid shall not exceed $600,000, and the amount expended at the head of the Atchafalaya and the mouth of Red River for the rectification thereof, pursuant to the plan heretofore adopted, including keeping open a navigable channel through the mouth of Red or Old River into the Mississippi River, shall not exceed $250,000.

The language above quoted makes several changes in the legislation under which the Commission has been acting, the most important of which is the removal of restrictions as to the building of levees. The appropriation was allotted as follows, viz: To levees, $1,200,000; to works of channel improvement, $1,239,000; to surveys and examinations, salaries, and expenses of Commission, $225,000; to harbors, including Red and Atchafalaya, $536,000.

Subsequently, by a joint resolution dated March 3, 1891, Congress provided a further appropriation, as follows, viz:

That the sum of $1,000,000 is hereby appropriated, to be paid out of any money in the Treasury not otherwise appropriated, for the improvement of the Mississippi ver from the Head of the Passes to the mouth of the Ohio River, which sum shall immediately available and shall be expended under the direction of the Secretary War in accordance with the plans, specifications, and recommendations of the ssissippi River Commission: *Provided*, That no portion of this appropriation shall xpended to repair or build levees for the purpose of reclaiming lands or prevent- injury to lands or private property by overflows: *Provided, however*, That the mmission is authorized to repair and build levees, if in their judgment it should done, as part of their plans, to afford ease and safety to the navigation and com- ce of the river and to deepen the channel: *Provided, further*, That the office, ical, and traveling expenses, and salaries of the Mississippi River Commission be paid from this appropriation.

The Commission being doubtful of its authority to recommend the use of this later appropriation for levees in some parts of the river where levee work had been begun and where further work was deemed essential, the sum of $250,000 was withdrawn from the previous allotments to works of channel improvements, and reallotted to the protection of existing levees from danger threatened by high water. This sum was replaced from the latter appropriation, and the remaining $750,000 was then alloted as follows, viz, to works of channel improvement, $650,000, and to harbors $100,000. Subsequently the necessity of extensive works at Memphis was developed, and $105,000 was withdrawn from works of channel improvement and added to the allotment for harbors.

The total amount, $1,450,000, allotted to levees was distributed as follows, viz:

Second District—	
Upper Mississippi Levee District	$105,250
White River Basin	192,500
Third District—	
Lower Mississippi Levee District	230,750
Tensas Basin in Arkansas	237,500
Tensas Basin in Louisiana	129,062
Fourth District—	
Tensas Basin	250,500
Right bank below Red River	174,250
Left bank below Red River	118,188
Local surveys and gauges	12,000
	1,450,000

The total amount, $1,784,000, finally allotted to works of channel improvement, was distributed as follows, viz:

First and Second Districts—	
Plum Point Reach	$517,500
Plant, First and Second Districts	130,500
Preservation of works, local surveys, and gauges	30,000
Third District—	
Lake Providence Reach	390,000
Ashbrook Neck	300,000
Plant	150,000
Local surveys, gauges, etc	12,000
General service	254,000
	1,784,000

The total amount, $741,000, finally allotted to harbors, was distributed as follows:

First District—	
Hickman, Ky	$500
New Madrid, Mo	1,000
Second District—	
Memphis, Tenn. (for temporary work, dredging)	15,000
Memphis, Tenn. (for Hopefield Bend revetment)	90,000
Helena, Ark	22,500
Third District—	
Greenville, Miss	200,000
Vicksburg, Miss	85,500
Fourth District—	
Natchez, Miss	1,500
Red and Atchafalaya	225,000
New Orleans, La	100,000
	741,000

Operations were resumed as soon as practicable after the first of these appropriations became available.

SURVEYS, GAUGES, AND OBSERVATIONS.

In the general survey of the river field work was resumed in the spring of 1891. The triangulation party began at Keokuk, Iowa, and worked northward. This party was also charged with the establishment of lines of permanent bench-marks across the valley. By the end of the year it had reached a point 4 miles above Burlington, Iowa, a distance of about 50 miles from the starting point. The triangulation is now completed from Donaldsonville, La., to this point. Two leveling parties were placed in the field. One began at St. Paul, Minn., and working southward, had at the end of the year reached Alma, Wis., a distance of about 95 miles. The other began at Duluth, Minn., and working towards St. Paul, had at the end of the year reached beyond Sturgeon Lake, a distance of about 54 miles. The line of precise levels had in previous years been made continuous from Biloxi, Miss., to Savanna, Ill., and thence to Chicago, Ill., connecting with Lake Michigan. The new work will eventually be connected with that line. It is expected that topographical parties will take the field about the 1st of August, 1891. The gauge at Grays Point, Mo., was reëstablished, and the other gauges were kept up and read daily.

In the office good progress was made in the preparation of the detail charts, scale 1:10,000, and of the topographical maps from Cairo northward, scale 1 inch to 1 mile. A profile of the Mississippi was prepared, showing the right bank and levees from Cairo, Ill., to Donaldsonville, La., and the left bank with levees from Memphis to Vicksburg. Additional sheets, fifteen in number, of the 1:20,000 charts were published, making seventy-one sheets in all which have now been published, covering the river from Donaldsonville, La., to Cape Girardeau, Mo. Ten sheets of a revised edition of the 1 inch to 1 mile maps, below Cairo, were also published. The recomputation of the discharge measurements made in 1887-1889, and 1890, was completed, and recomputation of the discharge measurements made during the high water of 1891 was begun. The daily records of the gauges kept by the Commission, and of certain others kept under the Chief Signal Officer, and under Major Mackenzie and Captains Willard and Taber, of the Corps of Engineers, were received, tabulated, and printed. The record includes thirty gauges at various points upon the Mississippi River from Hastings, Minn., to Carrollton, La., and twenty-two gauges upon tributaries, and three upon the Atchafalaya. A hydrograph in three sheets, showing the stages of the Mississippi and its principal tributaries from St. Louis, Mo., to Carrollton, La., by 10-day means for about 20 years, was prepared, and an investigation was made of what changes in depth, if any, had occurred at the head of the Passes. For details of this and of other work of a miscellaneous character, see report of Capt. Carl F. Palfrey, the secretary of the Commission, Appendix C.

GENERAL SERVICE.

The "general service" was originally established with headquarters t St. Louis for the purpose of furnishing to the various districts such ıpplies as could not be procured within the limits of the districts and ɔuld not be conveniently obtained by the officers in charge of the disricts by direct purchase. As the work advanced and markets were ɩeveloped, the duties of this branch of the organization were gradually estricted, until of late years they have been limited almost exclusively ɔ supplying stone from the upper part of the valley to the first, second,

and third districts. For several years past the office has been in the same building with that of surveys, gauges, and observations, and has been managed by the same officer, the secretary of the Commission. Further steps towards consolidation of the two offices and a reduction of the clerical force were taken this year.

There were shipped to the first, second, and third districts, 20,795 cubic yards of stone. This includes a barge load lost, and a small quantity en route at the end of the year. Extensive repairs were made to the fleet. It is now all in good serviceable condition, with the exception of the steamer *Mississippi*. That vessel will be repaired at an early day. For further details see report of Captain Palfrey, Appendix C.

COMMERCIAL STATISTICS.

Commercial statistics for the calendar year 1890 were collected. The tonnage of the vessels employed upon the river below Cairo, as registered at the custom-houses of Pittsburg, Cincinnati, and St. Louis, was 125,257 tons. Information as to the quantity of freight brought from the middle Mississippi, above Cairo, is quite full, but as to that brought from the Ohio, it is incomplete. The total amount of river traffic below Cairo, for the year 1890, is estimated to be about 2,295,000 tons. For details see report of Captain Palfrey, and of the district officers, Appendices C, D, E, and F.

FIRST DISTRICT.

(Cairo to foot of Island No. 40, 220 miles.)

(a) Columbus, Kentucky, 21 miles below Cairo.—Work at this locality has been carried on under specific appropriations in the acts of 1886 and 1888, amounting together to $43,750. The project provided for a revetment of five spur dikes to protect about 2,200 linear feet of bank which was threatening to cave. At the beginning of the fiscal year two of the dikes had been completed, and two more had been begun, but the work was suspended on account of high water. Work of construction was resumed in September and terminated in the following month, the funds being exhausted. The original project had been carried out, except that one of the spur dikes was not entirely completed. It was advanced sufficiently far, however, to accomplish what is required of it. The efficiency of the system is not impaired. No further appropriation for this locality is at present required.

(b) Hickman, Kentucky, 36 miles below Cairo.—The acts of 1886 and 1888 contain specific appropriations for this locality, amounting together to $88,750. The evil to be remedied was the caving of the bank in front of the town. Owing to the existence of a projecting point of tough clay a short distance above the landing, it was possible to accomplish the desired result with an unusually small development of work. A continuous revetment about 1,000 feet long, extending downstream from the clay point, was placed in October, 1890. Except for some slight damage at the downstream end during the recent high water, it remains in good condition. No work was done this year. Above the clay point caving continues, but there appears to be no public interest which is suffering sufficiently to justify the large expenditure which would be required to perfect that portion of the bank. Should the clay point finally yield, then additional expenditures will be required to maintain the work now in place. The amount remaining unexpended at

the beginning of the fiscal year was $48,647.78. The War Department having decided that the terms of the act of September 19, 1890, quoted in the beginning of this report, required an allotment to this locality, the sum of $500 was allotted from the appropriation contained in that act. These two sums are now available. To protect the bank above the clay point an additional appropriation of $110,750 will be required. It is not recommended. During the coming year a resurvey will be made and the locality will be watched, but it is not expected that any considerable expenditures will be required.

(*c*) *New Madrid, Missouri, 71 miles below Cairo.*—In obedience to the requirements of the act of September 19, 1890, as interpreted by the War Department, an allotment of $1,000 was made to this locality. It will be employed in making a survey during the coming low-water season. There has been some caving of the bank in front of the town, which the inhabitants desire to have stopped. The Commission is unable to recommend the diversion of any of the funds appropriated for the general improvement of the river, to this purpose at this time. The projected survey will furnish the data necessary for estimating the extent and cost of the protection desired.

(*d*) *Plum Point Reach, 147–186 miles below Cairo.*—The works thus far undertaken in this reach, arranged geographically, beginning at the upstream end, are, 1. Daniels Point; 2. Ashport Bend revetment; 3. Gold Dust dikes; 4. Fletchers Bend revetment; 5. dikes in chutes of Elmot Island, and Island 30; 6. Plum Point revetment; 7. Plum Point dikes; 8. Osceola Bar revetment; 9. Bullerton revetment; 10. Osceola and Bullerton dikes. They are distributed over a length of about 20 miles, some on one side and some on the other, of the river. They constitute one connected whole, each one being essential to the effectiveness of the others. The continued efficiency of all is dependent upon the maintenance of the conditions as to approach of the river from above which obtained when they were planned. The order in which they were begun is different from the one just given, the object being first to obtain the desired results in the shape of a deepened channel and improved navigation, and then to maintain those results by repairs and extensions of the works themselves, and by the addition of such new works, higher upstream, as might become necessary. Thus the latest addition to the works is the one mentioned first on the above list, while the one which requires the heaviest expenditure from the late appropriations is the second.

(*d 1*) *Daniels Point revetment.*—Rapid caving having developed in the long bend known as Canadian Reach, of which Daniels Point is the foot, and there not being sufficient funds to undertake the protection of the entire bend when the appropriation of 1888 became available, it was determined to protect about a mile of the downstream end. As reported last year, a continuous revetment 5,300 feet long was placed. The revetment as a whole has stood well, but the bend above it has continued to cave, giving to the upstream end of the revetment a salient position. It has suffered some damage at this point. To maintain it, it must be extended 500 or 600 feet upstream. It is proposed to do that work during the coming year.

(*d 2*) *Ashport Bend revetment.*—The protection of Ashport Bend was one of the first works projected in this reach. A short piece of revetment was placed in 1882, but more pressing demands for funds at other places has heretofore prevented a continuation of the work. Since that date the caving, though not rapid, has been progressing. The bank has receded so far that it must now be held to avoid an injurious change

in the action of all the works in the Plum Point Reach. Moreover, the caving has in parts of the bend recently become more active. Between October, 1890, and May, 1891, there was at one place a maximum recession of 300 feet. It is proposed during the coming year to protect the entire bend with a continuous revetment of brush and stone.

(*d 3*) *Gold Dust dikes.*—These dikes, begun in 1882, had for their object to close the chute behind Elmot Island. No work has been done upon them for several years, and none is proposed. They have caused heavy deposits and have greatly restricted the chute, though they have not completely closed it. They have suffered the natural deterioration due to the circumstances of the case, and are now in a ragged condition. It is believed that the complete closure of that chute can be accomplished by works in the lower or middle portion of it better than by a restoration of these dikes.

(*d 4*) *Fletcher Bend revetment.*—The protection of this bend was begun in 1884 and suspended in January, 1885, in an unfinished condition. Owing to restrictions contained in the act of 1886, by which expenditure of the funds appropriated in that act for works of bank protection were prohibited, this work could not be resumed until the autumn of 1888. It had then suffered some damage, but the most serious result of the suspension was the change in the form of the bend. Unprotected parts had caved back, leaving protected parts in a salient, and making the shape of the bend so awkward that it was deemed expedient to sacrifice the work protecting one of these salients. Nothing has been done here since September, 1889. The protection now consists of one piece of continuous revetment 7,800 feet long, beginning at the upstream end of the bend, then an interval 3,800 feet long of unprotected bank, and of four detached blocks of revetment, each about 1,100 feet long, near the downstream end of the bend. The latter are separated from each other by intervals of 300, 400, and 500 feet. They have been constructed in this manner as an experiment. The total length of bank from the extreme upper to the extreme lower end of the work is 17,200 feet. It is proposed during the coming year to extend the continuous revetment downstream so as to close the interval of 3,800 feet. There has not as yet been any great strain upon the experimental system of interrupted revetment, and it has accordingly not been demonstrated that the intervals purposely left there must be closed.

(*d 5*) *Dikes in chutes of Elmot Island and Island 30.*—These dikes, begun in 1889, were designed to complete the closure of the chute behind Elmot Island, thus supplementing the Gold Dust system (*d 3*). The Elmot Chute being divided near its lower end into two chutes by Island 30, two dikes were required, and they have been named as above, though in effect one is but a continuation of the other. In the last annual report they were reported, on June 1, 1890, to be within a few days of completion. A few days later a break occurred in the Island 30 Dike. It was repaired in July. In November a break occurred in the Elmot Dike. It was repaired during the winter. In February bad breaks occurred in both dikes, and in March another break in the Elmot Dike. All this appeared to demonstrate that permeable dikes were not well adapted to this locality; that is, to a large arm of the river where the obstruction must extend from one bank to the other and no means of escape could be provided for the masses of drift entering it. Great difficulty had previously been experienced with dikes built to the height of a medium stage. Drift accumulating in large masses and lifted above the dike with the rising river would often lift the dike with it, or in any event would exert greater destructive power than when resting against

it. The great height given to these dikes was adopted with the hope that by preventing drift from running over them they might be relieved from that source of danger. They were given extra strength to enable them to resist the greater direct pressure. But it appears that the strength is not sufficient, and that to make it so will increase the cost above that of other methods of accomplishing the desired object. It is proposed, therefore, to not repair these dikes further, and to build during the coming year a low solid dam of brush mattresses ballasted with stone, to complete the closure of the chute. The dikes have nevertheless contributed towards that object by causing considerable deposits.

(*d 6*) *Plum Point revetment.*—Some local caving having begun on the upstream side of Plum Point, a short piece of revetment 800 feet long was placed there in 1889. It remains generally in good condition, the slight damage at its downstream end not having impaired its efficiency. Nothing was done during the year, and it is not at present evident that anything will be required during the coming year.

(*d 7*) *Plum Point dikes.*—These dikes, begun in 1883, have required but little attention since 1885. They are buried in deposits, and have fully accomplished the object of contracting the width of the river for which they were constructed. Supplementary dikes at Yankee Bar, a mile further downstream, have at times appeared to be desirable, but they are not immediately necessary and will not be undertaken during the coming year.

(*d 8*) *Osceola Bar revetment.*—Rapid caving of the channel face of Osceola Bar, or Towhead, having begun, a continuous revetment of brush and stone was undertaken this year as soon as the work could be organized after the appropriation became available. It was begun in November at the downstream end of the Towhead, that being the part where immediate protection was most essential, and was extended upstream until operations were stopped by high water in February. The length of the protection placed was 4,500 feet. An inspection since the recent high water shows it to be in perfect condition. It is proposed to extend it further upstream during the coming year. The original project under which it was begun contemplated a total length of about 7,000 feet, but recent changes in the position of the channel may reduce that amount considerably.

(*d 9*) *Bullerton revetment.*—The revetment of the channel face of Bullerton Towhead, constructed in 1882–1884, remains in serviceable condition. It has not required attention for several years.

(*d 10*) *Osceola and Bullerton dikes.*—The system of dikes designed to close the chutes behind Osceola and Bullerton towheads were begun in 1882 and essentially completed in 1885. They resulted in shutting off nearly all though not all water, and in filling the chutes almost entirely with deposits, with great resulting benefit to the main channel. There is no flow through them at a 10-foot or lower stage. The results remain, though the dikes themselves are much decayed and are in a ragged condition. To maintain the results and to complete the closure of the chutes, it has not been considered necessary to restore them all. A single dike, known as Bullerton No. 2, was reconstructed in 1889, and is now in serviceable condition. Nothing was done here during the year, and nothing is proposed for the coming year, except to keep the dike mentioned in repair.

Results in Plum Point Reach.—The river did not reach a very low stage during the year. The least depth found in the improved part of the reach was 12 feet. The favorable results heretofore reported were maintained. The depth since the works were begun having been

doubled, the navigable capacity of this portion of the stream has been multiplied by 8.

(*e*) *Surveys, gauges, and observations.*—Discharge observations during the high water of 1891 were made at Columbus, Fulton, and Plum Point. Two hydrographic surveys were made of the Plum Point Reach, one in October, 1890, and the other in May, 1891. The gauges were read daily throughout the year at all the stations.

(*f*) *Levees.*—The only levees constructed by the United States in the first district are the two short detached pieces in the vicinity of the Plum Point Reach, built in 1886–1888. A piece of the Tennessee levee, near its downstream end, caved into the river. The remainder of the line required only trifling repairs. There is no general system of levees maintained by local authorities within the limits of this district.

A survey for the location of a line of levees along the St. Francis front was made in 1888 and 1889. The office work of reducing the notes and preparing the profile was completed this year. The line surveyed extends from Point Pleasant, Missouri, to Council Bend, Arkansas, a distance of 200 miles. It includes 23 miles of levee already built on that side of the river near Plum Point, leaving 177 miles to be constructed.

For details of the operations in the first district, see report of Capt. S. W. Roessler, Appendix D.

SECOND DISTRICT.

(Foot of Island No. 40 to mouth of White River, 180 miles.)

(*a*) *Memphis, 230 miles below Cairo.*—Works for the preservation of the harbor of Memphis include the protection of the city front and of Hopefield Bend, above and on the opposite side of the river. The latter work was begun in 1882, but for reasons given in previous reports it could not be completed until February, 1889. By that time the downstream end of the bend had receded so far that the approach of the river to the Memphis landing was no longer favorable to the maintenance of the upstream portion of the landing. As reported last year, a bar had formed here in front of the landing, where there are some important business interests, such as the grain elevator and railway transfer. During the low-water season of 1890 a channel was dredged through this bar, and there was no interruption of steamboat traffic to the elevator. It is proposed to repeat the dredging in advance of the coming low-water season.

The revetment of Hopefield Bend suffered some injury during the high water of 1890, a piece 762 feet long of the work of 1887 being destroyed. This was replaced last autumn. During the recent high water the portions above the water surface suffered some injury, the subaqueous parts remaining intact. It is proposed to restore the revetment during the coming year.

The protection of the city front was begun in 1878, before the organization of the Commission, at the upstream end of the landing. With the changes in Hopefield Bend the point of attack has moved downstream and the protection has from time to time been extended in that direction. The most recent work is the system of spur dikes, known as the "Citizens Protection," originally built in 1886 with funds subscribed by property owners in the vicinity, the work being executed under the direction of the officer in charge of the district with plant belonging to the United States. They were raised and covered with stone

by the Commission in 1889. They as well as the revetments higher upstream remain in good condition. There are indications that it will be necessary to extend the protection downstream, but it is not proposed to undertake that this year.

(*b*) *Helena, 306 miles below Cairo.*—The act of August 11, 1888, contained a specific appropriation of $75,000 for this locality. The project adopted had for its object the protection of about 3,000 feet of bank in front of the town, and contemplated a construction of 5 spur dikes, one piece of revetment 600 feet long, and a drainage canal to prevent sipage. As reported last year, the funds were not sufficient to entirely complete the project. The continuous revetment, the drainage canal, and two of the spur dikes were completed. The remaining three spur dikes were left in an unfinished condition. Nothing was done here during the year: The works have suffered no injury. An allotment has been made for continuing them during the coming year, but as caving has ceased it is possible that that will not be necessary.

(*c*) *Surveys, gauges, and observations.*—Discharge observations during the high water of 1891 were made at Memphis and Helena. Several local hydrographic surveys were made at Memphis. The gauges were read daily throughout the year at all the stations.

(*d*) *Levees.*—The levees in this district include the White River Front, on the right bank, extending from Helena to and including Laconia Circle, a distance of about 78 miles by river, and on the left bank so much of the Yazoo Front as lies within its limits, a distance by river of about 120 miles. The lengths of levee are much shorter than these distances. Work was carried on during the year upon both fronts. Upon the White River Front a line was surveyed connecting the levee of Helena with that at Laconia Circle. The allotment to this front, $192,500, was subdivided so as to provide $80,000 for extending the levee near Helena southward from its present terminus, which is about 15½ miles below Helena, and $100,000 for strengthening the river side of Laconia Circle and extending that levee northward, and reserving $12,500 for protection during high water. The expenditure of the first-mentioned sum has been deferred until the coming year, for the reason that after twice advertising satisfactory terms for doing the work could not be secured. At and above Laconia Circle the work covered a total length of a little over 18 miles. Of this 90,300 feet consisted in closing old crevasses and in enlarging the old levee from a point 59,600 feet below the town of Laconia to a point 30,700 feet above it, and 6,000 feet was in new levee extending northward. The total length of this line is about 59 miles. The 18 miles worked over this year, and the 15½ miles previously existing below Helena, leave about 25 miles to be constructed to afford fair protection to this front. Exactly what portion of this can be covered with the $80,000 available can not be determined until new prices are obtained after due advertisement. In portions of the line there are old and dilapidated levees which can be utilized. In all of the new work the crest was raised to a height of 1½ feet above the high water of 0.

n the Yazoo Front the $80,000 allotted to the Upper Mississippi Levee trict (State organization) were applied to raising and strengthening levees at Grants Pass, sections 60 and 61 (312 L),* Delta to Friars nt, sections 65, 66, and 67 (314–319 L), Hushpuckana Crossing (353

n this report the number and letter in brackets after the name of a levee show istance in miles below Cairo, and the bank of the river, whether right or left, n which it lies.

L), Robinsonville (354 L), and Appersons Field (355 L). The grade was raised to a height of from 2 feet in some cases to 4 feet in others above the highest water recorded. In addition to this much work was done by the local authorities, the amount and location of which has not been reported to the Commission.

For details of the operations in the second district, see report of Capt. S. W. Roessler, Appendix D.

THIRD DISTRICT.

(Mouth of White River to Warrenton, Miss., 220 miles.)

(*a*) *Lake Bolivar Front, 417 miles below Cairo.*—The work at this place was undertaken in accordance with a requirement of the act of August 11, 1888. The object was to stop the caving of the bank which threatened the large levee across the end of Lake Bolivar. A continuous revetment 4,400 feet long was placed during the latter part of 1888 and early part of 1889, and some repairs were made in 1890. Nothing was done during the year. The work remains in good condition and has stopped all caving where it is placed, removing all apprehension for the safety of the important levee which it was designed to protect. Farther downstream the caving continues. It would be desirable to extend the work in that direction, but as the resources of the district will be taxed to the utmost in meeting demands which are more pressing, it is not proposed to do anything here during the coming year.

(*b*) *Ashbrook Neck, 446 miles below Cairo.*—The neck which separates Georgetown Bend from the bend below had, from progressing caving, become so narrow that the danger of a cut-off had become imminent, with all its attendant disasters to navigation and to riparian owners. Great injury to the town of Greenville in particular would probably result from such an occurrence. The distance across the neck had become but 2,300 feet, while the distance by river was 9 miles. The work of protecting the upstream side of this work was begun in November last and continued until stopped by high water in January. At that time a continuous revetment had been placed, covering 2,820 linear feet of bank. It was located so as to proteet the narrowest part of the neck, where caving had been most active. During the subsequent high water it was subjected to enormous and unusual strains which it endured in a very satisfactory manner. Except for a short distance near its downstream end, where it was constructed during a high and rising stage of the river, and of less than the standard width and where there has been some settlement, the work now stands intact. To check the flow across the neck two lines of slashings, about 900 feet apart, one 7,000 feet long and the other 6,400 feet long, were made parallel with the axis of the neck through the forest of saplings which covers it. The trees were cut off about 6 feet from the ground and the tops were then wattled in among the stumps. These obstructions caused some considerable deposits and aided in averting the threatened disaster for this year, but they are of too slight and temporary a character to be relied upon permanently to prevent dangerous flow across the neck. For that purpose a substantial levee will be required. The whole work was begun and prosecuted under pressure of threatened danger. It is proposed to resume the construction of the revetment as soon as practicable, and to extend it both upstream and downstream.

(*c*) *Greenville, Mississippi, 478 miles below Cairo.*—The work at this place, begun in 1887, had for its object the protection of the bank in front

of the town, which was caving rapidly. The ten spurs originally constructed for that purpose accomplished the object, and have continued to hold that portion of the bank; but the long bend above the city was caving rapidly over a length of several miles. If that caving should continue it was only a question of time when the incursion of the river above Greenville, into the alluvial plane upon which the town stands, should be deep enough to take the town and its protection in flank. The certain way to protect Greenville was to protect the bend above, throughout its length. This would involve an expenditure of about half a million dollars, a sum which was not available either immediately or prospectively. The best that could be done was to protect the downstream end of the bend near the town. Some efforts were made in that direction in 1888 and in 1889. Two additional spur dikes 500 feet apart were built in 1889, and about 1,500 feet and 2,000 feet higher upstream than the original system of ten. The bank above them continuing to cave, they were left in a salient and subject to extraordinary strains. When the new appropriation became available last autumn they had suffered material injury. The repair of these and the construction of additional works of revetment further upstream had become urgent, but the condition of the plant was such that it was entirely impracticable to begin them before the high-water season. During the high water of this spring the caving in the bend above continued more rapidly than ever. It resulted in the entire destruction of the two spurs of 1889, and then of an extraordinary recession of the bank which they had been protecting. The shore line is now from 800 to 900 feet in rear of where it was while the spurs stood. The caving has extended down to the work of 1887–'88, and has cut off two of those dikes at the upstream end of the system. It is proposed during the coming year to build a continuous revetment about 6,500 feet long extending upstream from the second of the 1887–'88 spurs. It is expected to begin the work as soon as the stage of the water will permit.

(*d*) *Lake Providence Reach, 517–552 miles below Cairo.*—The works undertaken for the improvement of this reach, and begun in 1882 and 1883, were systems of permeable dikes, or contraction works at Duncansby, Cottonwood, Mayersville, Elton, Baleshed, and Stack Island—constituting an almost continuous series of dikes from Duncansby to Stack Island, a distance of 12 miles, and of bank protection at Louisiana Bend and Mayersville Island. Louisiana Bend was higher upstream than any of the others, and the direction of approach through that bend fixed the plans of the others. The preservation of Louisiana Bend in the shape in which it then existed was vital to the permanent success of the other works. The protection of that bank from caving was a work without precedent. No bank so friable of a stream so deep and so swift had ever been protected. Nevertheless, the work of protection was begun in 1883, with full confidence that it could be carried through to success. Accidents might occur, and the earlier work would perhaps be less perfectly adapted to the case than what would be employed after some experience here, but it was not doubted that with the means at the disposal of the Commission the accidents could be repaired, and the bank held. During the high water of the spring of 1885 very extensive injury was suffered by the revetment, of which about 12,500 linear feet had beeen placed. The next appropriation act prohibited the use of money upon revetments. The result was that this work was soon afterwards finally and completely destroyed, and it was not until the restrictions as to bank protection were removed by the act of August 11, 1888,

that the attempt to hold Louisiana Bend could be renewed. By this time the bend was no longer in the position which it occupied in 1883. The river had moved a distance greater than its own width. The curves of the channel throughout the reach below were reversed. The plans were all upside down. Except at Baleshed and Stack Island, the works have been destroyed. For this reason it will not be profitable to sketch in outline the history of each work. It may be said in general terms that the contraction works largely accomplished the object for which they were constructed, at least temporarily. They certainly improved the navigation very much, and these results still remain. But the river is not yet under control in the Lake Providence Reach, and it is not certain that the results are permanent.

A new protection was begun in Louisiana Bend in 1889 and completed for a length of 6,024 feet. It has been through the floods of 1890 and 1891—in this vicinity the two highest upon record—and now stands intact. Nothing was done during the year, all of the plant which could be repaired in time being more urgently required elsewhere. It is proposed during the coming year to extend the work towards the foot of the bend.

(*e*) *Vicksburg, 599 miles below Cairo.*—The works for the maintenance and improvement of Vicksburg Harbor consist, first, of the revetment of Delta Point to prevent its further recession, which would allow the river to abandon the present Vicksburg front entirely instead of partly, as is now the case; and, second, of a dredged canal leading to a dredged basin at the upstream part of the city front.

The Delta Point revetment, covering 10,700 linear feet of bank, was constructed between 1878 and 1884. It has required no repairs for several years, and is now in good condition. Higher upstream the bank continues to cave, and it will probably be necessary to extend the revetment in that direction in the future, but it is not proposed to do that in the coming year.

At the date of the last annual report dredging was in progress in the canal. It was continued until August, when it was suspended on account of low water. The canal had then been excavated to the plane +8 feet on the Vicksburg gauge, but the side slopes being nearly vertical soon began sliding into the canal, so that a navigable depth to that plane was not attained. Dredging was resumed in March, 1891, and by the 1st of June, 1891, 164,000 cubic yards had been excavated. The work is still in progress. It is expected that with funds now available the canal and basin can be cut down to the level +3 feet on the Vicksburg gauge. A fill of about 28,000 cubic yards from river deposits, between August and February, was noted.

(*f*) *Surveys, gauges, and observations.*—Discharge observations during the high water of 1891 were made at Arkansas City, Ark., and Wilsons Point, La. Hydrographic surveys were made near Bolivar Front, Ashbrook Neck, Greenville, Louisiana Bend, and Mayersville. The gauges were read daily throughout the year at all the stations.

(*g*) *Levees.*—The levees in this district include the upper half of the Tensas Basin, a distance by river of about 181 miles on the right bank, and on the left bank of the lower half of the Yazoo Basin, a distance by river of about 206 miles. The lengths of levee are much shorter than these distances. Work was carried on during the year upon both fronts. To conform to local divisions, the right bank is subdivided into Tensas Basin in Arkansas and Tensas Basin in Louisiana. In the former subdivision the following lengths of new levee were undertaken,

viz, 902 feet at Brooksfield (425 R), 1785 at Boggy Bayou (426 R), 16,524 feet in the Lucca Loop extension (428 R), 1,630 feet at Luna (467 R), 1,480 feet at Columbia (469 R), 4,670 feet at Leland (470 R), 16,330 feet at Sunnyside (487–490R). At the date of last inspection none of the contracts were completed, but it was expected that all except the Lucca Loop work would be practically completed by the 30th of June, 1891. The contract for that levee does not expire until the 1st of February next. In all cases the new levees were being built to a height 3 feet above high water of 1890, and with an 8-foot crown. In addition to the work done by the Government in this subdivision, the Tensas levee board of Louisiana constructed, of new levee, 963 feet at Sappington (430 R), 471 feet at Ferguson (430 R), 1,291 feet at Arkansas City (438 R), and repaired and strengthened 12,900 feet north of Arkansas City; and the Desha levee board built 650 feet of new levee at Chicot. The quantity of embankment contracted for by the Government was 707,702 cubic yards, and by the local authorities 90,534 cubic yards. The older levees are of a flimsy character. The amount of material required to raise them, from Amos Bayou to the Louisiana line, to a height 3 feet above high water of 1890, with an 8-foot crown, is estimated to be 7,003,524 cubic yards, exclusive of the work now under contract. But this will not fully protect the head of the Tensas Basin. To do that it will be necessary to extend the line northward to connect with the levees on the Arkansas River, and to repair and strengthen the Arkansas River levees for some distance up that river, which involves the placing of several millions yards more.

In the Tensas Basin in Louisiana—the portion of it belonging to the third district—work was confined to a new levee at Elton (540–542 R.). The amount of embankment is about 353,587 cubic yards. It is expected that this contract will be completed early in July. The profile of the old levees in this subdivision is much stronger than that of those in Arkansas. It is estimated that about 2,796,000 cubic yards of embankment will be required to raise them to a height 3 feet above high water of 1890 with an 8-foot crown.

On the Yazoo Front the third district covers the local organization known as the Lower Mississippi levee district, and overlaps for 28 miles upon the Upper Mississippi levee district. The work undertaken was all in the former subdivision, and consisted of the enlargement of old levees. It covered 10,025 feet at Timber Lake (441–443 L), 10,000 feet at Port Anderson (443–444 L), 72,265 feet at Offuts Front (444–478L), 14,500 feet at Longwood (502 L), 6,570 feet at Clover Hill (534 L), 6,580 feet at Upper Skipwith (528 L), and 5,641 feet at Lower Skipwith (529 L). The levees at these places were raised to a height of from 1½ feet in some places to 3½ feet in others above the actual high water in 1890. At the date of the last inspection none of the contracts were completed, but it was expected that all except those for Timber Lake and Clover Hill would be completed by June 30, 1891. The total yardage contracted for by the Government was 601,916 cubic yards. he Government also constructed two loops above Greenville, of about ,000 cubic yards. In addition to this work the Lower Mississippi vee board placed 1,492,973 cubic yards at various points not reported the Commission. The yardage required to raise the levees in this strict to a height 3 feet above the calculated high water of 1890, with crown of 8 feet, is estimated to be 8,193,000 cubic yards.

For details of the operations in the third district, see report of Capt. McD. Townsend, Appendix E.

FOURTH DISTRICT.

(Warrenton, Miss., to Head of Passes, 484 miles.)

(*a*) *Natchez and Vidalia, 700 miles below Cairo.*—This locality first received the attention of Congress in 1879, when by joint resolution dated June 28, of that year, a survey was ordered. It was made by the Engineer Department of the Army, and the cost of the improvement was estimated to be $939,600. An appropriation of $40,000 was made in the act of June 14, 1880. Though it was difficult to find any way to apply this small amount to advantage, it was thought that the best chance of getting some result from it would be to protect a portion of Marengo Bend, with a view to preventing a junction of the river with Lake Concordia. It was so applied and was lost. The act of May 3, 1881, contained a further appropriation of $50,000. By this time the threatened junction of the river with Lake Concordia had occurred, and it was thought best to apply the funds to beginning the protection of Giles Bend above. This was done and the work was subsepuently lost. The work came under the jurisdiction of this Commission in 1882, with an unexpended balance of about $8,000. Since that date no special appropriation has been made, but the locality has been mentioned with other harbors in several of the acts appropriating money for the improvement of the river. It has continued to receive the attention of the Commission, though no attempt has been made to begin the work of construction. Experience here has shown, what has so often been demonstrated elsewhere, that it was useless to begin the work with inadequate means. A new survey was made in 1884, and a revised estimate was submitted. An experimental form of construction was suggested, and it was reported that the cost by that method, if successful, would be $700,000, and that if unsuccessful the cost by an alternative method would be at least double, or $1,400,000 (see Annual Report for 1884). At least one-half the first-named amount should be available before the work is begun, and it should be followed up by the annual expenditure of an equal sum until the work is completed. The Commission has never had at its disposal amounts of money so great as to justify the diversion to this locality of such sums as this. The small balance of 1882 has been expended in the care of the public property belonging to the work and in surveys. The act of September 11, 1890, as interpreted by the War Department, requiring some allotment to this place, a sum sufficient for a new survey was allotted and a survey was ordered. The field work was completed about the end of May. The report, which has not as yet been received,* will show what changes have occurred since the previous survey, and will form the basis of a new estimate of cost; but otherwise the situation will be the same as before. The caving in the bends continues, and danger to the Natchez landing is threatened, but the Commission is helpless in the matter.

(*b*) *Rectification of the Red and Atchafalaya Rivers, 764 miles below Cairo.*—The project adopted for this locality has for its objects (1) to limit the outlet capacity of the Atchafalaya, and (2) to improve the low-water navigation from the Mississippi into the Atchafalaya and also into the Red River.

The first of these objects is to be accomplished by the construction of a series of dams in the Atchafalaya, submerged sufficiently to permit navigation over them. At the date of the last Annual Report two of the

* This report has since been submitted.

projected dams, Nos. 1 and 3, had been constructed near Simmsport, in the Atchafalaya, about 5 miles below its head. Some repairs were made to the shore protection at the ends of these dams during the year, but nothing farther was done here. The dams remain in good condition.

The second object is to be accomplished by replacing the present single channel between the Mississippi and the Red-Atchafalaya, through which the flow is sometimes in one direction and sometimes in the other, by two channels, one for the inflow from the Red to the Mississippi, and the other for the outflow from the Mississippi to the Atchafalaya, and to prevent the Red River at low water from wasting itself down the Atchafalaya, by a dam which shall separate it from that stream at all stages below 10 feet. One of these channels is furnished by the present single channel, called Lower Old River, south of Turnbull Island. The other is to be created by the enlargement of Upper Old River, north of Turnbull Island, for the greater part of its length until it reaches the vicinity of Carr Point, and then continuing it to a junction with the Mississippi by excavation through Carr Point.

At the date of the last Annual Report the sill of the Red River dam had been placed. Work upon this dam was continued this year. The cribs for the first, second, and third tiers were fabricated, and a part of them were sunk into position, and preparations were under way for sinking the remainder. These will bring the top of the dam to the level of from 1 to 3 feet below low water.

Dredging in Upper Old River was begun in December and was stopped by high water on the 2d of February. About 30,000 cubic yards of excavation was made. The material was soft mud. The dredges were not well adapted to lifting it, and the trench was difficult to maintain, the semi-fluid sides flowing into it with much facility. The water way through Upper Old River has much diminished in size in the last few years, until now a narrow chute, which was dry in places at a 12-foot stage, is all that remains of it. The operation of dredging a channel through it will be difficult and costly, and will probably require different appliances from those now on hand.

To maintain the existing low-water navigation through Lower Old River some dredging was done as usual. Navigation was at no time stopped, though boats had trouble for some weeks in August.

The construction of a telephone line 30 miles long, to connect with West Melville, the nearest railway station, was begun.

(c) *New Orleans Harbor, 963 miles below Cairo.*—The city of New Orleans covers a length of about 13 miles of the Mississippi River. In that distance the river makes four bends, called the Corrollton, Greenville, Gouldsboro, and Third District bends. In all of them more or less erosion was going on, which, as the value of property increased, it became desirable to stop. The features of the case, which are peculiar and make it different from other places where the protection of banks has been undertaken, are: 1st, the great depth of water and steepness of the banks, which are unfavorable; 2d, the comparative stability of the banks, which has enabled New Orleans to occupy essentially her present site for a century and a half, which is favorable. The system of spur dikes was introduced in 1884 and has since then been used exclusively, and has thus far been successful. The spurs begin near the low water line and project into the river to the point where their top surfaces, having a slope of 1 upon 3, intersect the bottom. They are usually about 1,000 feet apart, but the interval may vary with the greater or less curvature of the bend.

At the beginning of the fiscal year there had been placed in New

Orleans Harbor 2 spurs in the Greenville Bend, 6 in the Gouldsboro Bend, and 4 in the Third District Reach, a little below the bend. During the year 3 spurs were built in the Carrollton Bend. They were all in good condition at the end of the year.

It is proposed during the coming year to place additional spurs in Carrollton Bend and the Third District Reach.

(*d*) *Surveys, gauges, and observations.*—Discharge observations during the high water of 1891 were made at Natchez, Red River Landing, and Carrollton, on the Mississippi, and at Simmsport on the Atchafalaya. Local surveys were made at Carr Point, Red River Dam, Atchafalaya Dams, parts of New Orleans Harbor, and in connection with levees, besides the survey at Natchez already mentioned. The old gauges were read daily throughout the year, and two new gauge stations were established, one above the Red River Dam, and the other at Fort Jackson.

(*e*) *Levees.*—The levees in this district include the lower half of the Tensas Basin and the Atchafalaya Basin on the right bank, a distance by river of about 432 miles, and on the left bank the low country below Baton Rouge, a distance by river of about 206 miles. Work was carried on during the year upon all three fronts.

In the Tensas Front the following lengths of levee were undertaken, viz: 3,030 feet at Bedford (606 R), 2,405 feet at Kempe (659 R), 13,888 feet at Gibson Landing (683 R), 3,355 feet at Ferriday (693 R), 578 feet at Arnauldia (702 R), 1,705 feet at Henderson (712 R), and 10,285 feet at Deer Park (722 R). They were to receive a height of from 1.8 feet in some places to 3 feet in others above high water of 1890, with a crown of 8 feet and slopes of 1 upon 3. By the end of the year all were completed except those at Gibson Landing and Henderson. An attempt was made to build a levee at Buckridge (624 R), and a contract was let, but property owners refused their consent to the line selected and the work was not undertaken. The total yardage in this subdivision undertaken by the Government was 587,260 cubic yards, of which 387,330 cubic yards were completed and paid for. It is proposed to complete the contracts before the next high water. Work was done by the local authorities, the amount and location of which has not been reported to the Commission.

On the right bank below Red River (Atchafalaya Basin) the following lengths of levees were undertaken, viz: 6,159 feet at Nina (806 R), 5,170 feet at Highland (815 R), 4,145 feet at Barroza (823 R), and 3,400 feet at Evergreen (857 R). They were to receive a height of 3 feet above high water of 1890 with a crown of 8 feet except at Nina, where it was 6 feet, and with slopes of 1 upon 3, except at Barroza, where upon the land side it was 1 upon 4. By the end of the year the levee at Barroza was finished, and good progress had been made upon the others. The total yardage in this subdivision undertaken by the Government was 482,411 cubic yards, of which 411,282 cubic yards were completed and paid for. It is proposed to complete the contracts before the next high water. Work was done by the local authorities, the amount and location of which has not been reported to the Commission.

On the left bank below Red River (locally known as the Pontchartrain Levee District), the following lengths of levee which had been begun by the local authorities were taken in hand and completed by the United States, viz: 4,813 feet at Shannon (837 L), 1,420 feet at Martinez (842 L), 4,423 feet at Gay (845 L), 3,135 feet at Woodstock (847 L), 4,540 feet at Hermitage (850 L), 7,400 feet at Grenada (856 L), 4,855 feet at Southwood (875 L), 4,032 feet at Ashland (878 L), 4,700 feet at Discharry (882 L), 1,325 feet at Irvine (892 L), 1,080 feet at Union (893

L), 2,269 feet at Lilly (900 L), 1,637 feet at College Point (903 L), 10,640 feet at Terre Haute (919 L), 1,336 feet at Cornland (922 L), 1,272 feet at Destrahan (939 L), and 7,350 feet at Frellson. All were completed before the recent high water. They were built to a height of 3 feet above high water of 1890, some of them with an 8-foot crown, and others with a crown of 5 and 6 feet, with side slopes usually of 1 upon 3, but in some cases of 1 upon 2. The total yardage placed by the Government was 431,877 cubic yards. The local authorities placed about half as much.

For details of the operations in the Fourth district, see report of First Lieut. John Millis, Appendix F.

HIGH WATER OF 1891.

The high water of 1891 was not of excessive height in the upper part of the valley. As far down as the mouth of the Arkansas River, 401 miles below Cairo, its height has been exceeded half a dozen times in the last 10 years. Below the Arkansas it was one of the highest upon record. At certain points, such as Lake Providence and Carrollton, it reached about the same height as that of 1890, which has never been exceeded. At other points it approached very closely to the height of 1890, while at others it fell short by from 1 to 3 feet of the height reached in 1890. The maximum discharge, as measured at Arkansas City, Wilson Point, and Natchez, was greater than that measured in 1890, while at Memphis, Helena, Red River Landing, and Carrollton it was less.

During the period of danger the district officers displayed their usual zeal in their efforts to hold the levees. The engineering staff had been stationed at critical points, sacks and lumber had been distributed, and all steamers required for transportation and inspections employed, and other necessary preparations made. Being well prepared in advance, and favored with reasonably good weather, they were able to obtain, in coöperation with the local authorities, a good degree of success. In accordance with rules established by the Commission, patrolling was generally left in the hands of the local authorities, the funds of the Government being applied exclusively to the labor and materials required to maintain the embankments. Exceptions to this rule were made in the case of levees built by the United States in localities where no local organization existed. No attempt was made to close a crevasse once opened, but efforts were made to hold the ends of the broken levees. The Commission considers the first of these rules essential to maintain the active interest of the persons most immediately interested in the maintenance of the levees, and the second to avoid extravagant expenditures.

There were in all but five crevasses during the flood. They were at Robinsonville (354 L), Stella (503 L), Concord (550 R), Ferriday (693 R), and Ames Plantation opposite New Orleans (963 R). There was also a break at Greenville, due to the levee caving into the river, but it had been anticipated and a new levee had been constructed behind it, which prevented damage from overflow. All except the first crevasse were below the Arkansas River. The aggregate length of all the breaks was [illegible]34 feet, or about one mile; this out of a total length of about 1,300 miles of levee below Cape Girardeau, Mo.

The Robinsonville crevasse attained a width of 550 feet. Its discharge was measured, but owing to an eddy the results are unreliable. Its further enlargement was prevented by the protection of its broken

ends, the Government furnishing the material and the local authorities the labor. It overflowed an area of about 62 square miles in Bolivar County and perhaps half as much more in Coahoma County.

The Stella crevasse attained a width of 422 feet and a maximum discharge of 19,000 cubic feet per second. Its enlargement was prevented by the protection of its broken ends. It overflowed an area of about 492 square miles, of which perhaps one-third would have been overflowed by back water from the Mississippi through the foot of the Yazoo Basin without any crevasse.

The Concord crevasse attained a width of 1,600 feet and a maximum discharge of 100,000 cubic feet per second. Its enlargement was finally checked by temporary dikes built out at right angles with its general direction. It overflowed an area of about 418 square miles in the third district and perhaps as much more in the fourth district.

The Ferriday crevasse occurred after the river had fallen considerably below its highest stage. It attained a width of 97 feet and a maximum discharge of about 3,400 cubic feet per second. It was readily closed. It inflicted only local injury.

The Ames crevasse attained a width of 1,665 feet and a maximum discharge of about 91,000 cubic feet per second. It overflowed an area of over 2,000 square miles, of which about one-tenth, or 151,000 acres, was under cultivation. It interrupted traffic upon three railroads. The damage which it inflicted to agriculture, live stock, drainage and canals, buildings, fences, and railroads is estimated by the district officer at over $8,000,000.

Besides these crevasses there was an opening in the levee at Henderson (713 R.), which had been made in 1890, and had not been closed. It attained a width of 1,075 feet, and a maximum discharge of about 26,000 cubic feet per second.

The Ames crevasse was caused by a badly constructed rice flume. The great Nita crevasse of 1890 was due to the same cause. These and other disasters have led the Commission to condemn the dangerous practice of placing rice flumes in the levees, and it has resolved that hereafter no levees shall be constructed or enlarged by the Commission in which any such device is to be placed or allowed to remain. No special cause could be assigned to the other crevasses. They occurred in old levees which were not suspected of being especially weak as compared with many other portions of their respective fronts. They were due to the inherent weakness of the embankments which pervades a very considerable portion of them. The process of strengthening the lines which has been going on from year to year, and is to be continued, has this year shown satisfactory results. The flood of this year did not differ greatly in volume from that of last year in the third district, though this year the weather was less unfavorable. In the second and fourth districts it was somewhat less in volume this year than last. In the second district there was no break last year, and but one this year. In the third district there were 17 breaks last year, with an aggregate length of about 3¾ miles, while this year there were but two breaks, aggregating 2,022 feet in length. In that district the overflow limits on the right bank include an area of 3,050 square miles, of which 2,500 were under water last year, and but 418 square miles this year; on the left bank the overflow limits include an area of nearly 2,000 square miles, of which 1,900 were under water last year, and but 554 this year. In the fourth district there were 27 breaks last year, having an aggregate length of over 2½ miles, while this year there were but two breaks, aggregating 1,762 feet in length. There are no data for comparing the

damage inflicted in this district last year with that of this year, but the Nita crevasse last year alone discharged more water than all of the crevasses this year.

FINANCIAL STATEMENTS.

Appropriation for salaries and expenses Mississippi River Commission:	
Balance on hand July 1, 1890	$116.50
Expended from July 1, 1890, to June 30, 1891	35.59
Balance on hand June 30, 1891	80.91
Appropriation for deficiencies Mississippi River Commission:	
Appropriated, act of March 3, 1891	1,950.00
Expended from March 3 to June 30, 1891	1,950.00
Appropriation for survey of Mississippi River:	
Balance on hand July 1, 1890	3,880.16
Expended from July 1, 1890, to June 30, 1891	3,873.08
Balance on hand June 30, 1891	7.08
Appropriation for improving Mississippi River:	
Balance on hand July 1, 1890	375,048.34
Appropriated, act of September 19, 1890	3,200,000.00
Appropriated, act of March 3, 1891	1,000,000.00
Refunded	21.00
Total	4,575,069.34
Expended from July 1, 1890, to June 30, 1891	1,518,989.35
Balance on hand June 30, 1891	3,056,079.99
Distributed as follows:	
Levees	724,955.32
Channel work	830,591.57
Harbors and bank protection	753,989.85
Red and Atchafalaya rivers	147,109.28
Surveys, gauges, and observations	143,548.24
Plant, general service, and miscellaneous	455,885.73
	3,056,079.99
Approximate outstanding liabilities and amounts covered by existing contracts	715,500.00

ESTIMATE OF FUNDS BY THE MISSISSIPPI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1893.

For improving Mississippi River from Head of the Passes to the mouth of the Ohio River, including salaries, clerical, office, traveling, and miscellaneous expenses of the Mississippi River Commission; for the building of levees; and for surveys from the Head of the Passes to the headwaters	$6,000,000
For work at harbor of—	
Memphis	25,000
Greenville	350,000
Vicksburg	175,000
Natchez	350,000
Red and Atchafalaya rivers	350,000
New Orleans	200,000

NOTE.—The Commission take the liberty to recommend that hereafter appropriation for the expenses of the Commission and the work of veys and observations shall be included in the appropriation for the provement of the river, as was done in the act of September 19, 1890. has occurred twice heretofore that money has been appropriated to

be expended according to the plans and recommendations of the Commission without any appropriation for its expenses. As the law expressly prohibits the creation of any liability against the Government for the payment of which no appropriation exists, the proper supervision and inspection of the works by the Commission becomes in such a case impracticable.

C. B. COMSTOCK,
Col. of Engineers, and Bvt. Brig. Gen.,
President Mississippi River Commission.
CHAS. R. SUTER,
Lieut. Col. of Engineers, U. S. A.
B. M. HARROD.
ROBERT S. TAYLOR.
O. H. ERNST,
Major of Engineers, Colonel U. S. A.
HENRY FLAD.
HENRY L. WHITING,
Asst. Coast and Geodetic Survey.

LIST OF APPENDICES ACCOMPANYING THE FOREGOING REPORT.

LIST OF PLATES ACCOMPANYING THE FOREGOING REPORT.

APPENDIX A.

REPORT OF LIEUTENANT-COLONEL CHARLES R. SUTER, CORPS OF ENGINEERS, UPON INVESTIGATION OF DISCHARGE MEASUREMENTS, MISSISSIPPI RIVER.

ST. LOUIS, MO., *August 3, 1888.*

GENERAL: Shortly after the organization of the Commission I was requested by the Committee on Levees and Outlets to undertake the study of the various discharge measurements which were then or would soon be available, with the object of determining, if possible, the variation of discharge with gauge height. The great importance of this question was very generally recognized, as it was expected that it would afford the means of determining the heights to which great floods would attain when confined between levees.

So far I am sorry to say these expectations have proved delusive; the problem instead of being a simple one has turned out to be one of great difficulty and complexity, and I am not as yet able to present to the Commission anything like a definite solution of it. Still, enough has been accomplished to at least clear up the ground, while incidentally facts have been brought to light to which I think much importance attaches. It is to some of these that I mainly wish now to call attention, but before doing so an explanation of the methods used and the results obtained in the discharge curve investigation will be necessary. I shall endeavor to be as brief as possible.

At the time this study was commenced there was available the series of discharge measurements made by the Delta Survey at Columbus, Ky., and Vicksburg, Miss., in 1858, and at Carrollton, La., in 1851. Also the measurements made under the direction of the Engineer Department in 1879 on the Mississippi at Columbus and Memphis, on Red River at Alexandria, on Arkansas River at Pine Bluff, on White River

*Not printed.

at Clarendon, and on the Missouri River at St. Charles and Sioux City. In 1879–'80 measurements on the Lower Mississippi were made under the direction of the Commission at Fulton, Tenn., and Carrollton, La. The next year, viz. 1880–'81, measurements were made on the Upper Mississippi at Prescott, Winona, Clayton, Hannibal, Grafton, and St. Louis.

In 1881–'82 the parties were again on the Lower Mississippi, and a series of measurements were made at Columbus, Helena, Hays Landing, Red River Landing, and at Paducah on the Ohio River. In 1882–'83 a series was measured at Carrollton. Finally, in 1884–'85, a new series was obtained at Point Pleasant, Helena, Arkansas City, Warrenton, Red River Landing and Carrollton. Besides these full series numerous isolated measurements have been made at various places, though these are of but little value in a study of this character.

The idea of a gauge-discharge relation, or, as it is generally termed a discharge curve, is simple enough. If the measured values of discharge be plotted on any convenient scale as abscissas, while the corresponding gauge readings are plotted as ordinates, a series of points are obtained through which a mean curve can be passed by well-known methods, which will express approximately the relation in question. This curve, so far as I am aware, has generally been taken to be a plain parabola, but my experience shows that it is generally a curve of a higher power.

Carrying out the method above described, provisional curves were soon obtained for all the points at which measurements were made from 1879 to 1882, and as far as the tributary streams are concerned I do not now apprehend that any great change in these curves will be found necessary, but when the 1882 observations became available it was at once seen that the discrepancies in the Mississippi curves were too great to be admissible and the whole subject was taken up anew. It was finally decided that, on the whole, the Fulton series of observations was the best, they having been made with great care under very favorable conditions, and being better balanced than any other series, while at the same time the range on the gauge was large, reaching from a very low stage to the beginning of overflow. It was argued that if a curve could be found here it would answer the purpose of a standard by which the irregularities noted elsewhere could be eliminated or properly valued. The only objection to these observations was due to the fact that at the high stages a heavy fill, now known to have been temporary, took place in the discharge section and destroyed the regularity of the observations. It was finally decided to transfer the measured values to Memphis, plotting them to the readings on the Memphis gauge, which occurred three-fourths of a day later. When this was done the irregularities disappeared and the curve, was duly computed. (See Plate No. 1.) This Memphis curve is taken as the standard curve for, as will be shown farther on, it not only expresses the relation of gauge to discharge at this special locality, but when equivalent values in terms of gauges at other localities are substituted for the Memphis gauge heights here used, it expresses this relation equally well for such other localities.

Premising that the curve thus obtained was found to agree very well with the Memphis discharge observations of 1879, I will now describe the method by which it was transferred to other points.

If the assumption be correct that a definite relation exists between gauge and discharge, then it follows that for equal discharges any two gauges should bear to each other some equally definite relation. Such is found to be the case, and a study of these gauge relations has been very instructive and fruitful of results. To determine them an ordinary sheet of cross-section paper is taken and marked on the lower and left-hand edges with the scales of the two gauges to be compared. Then, if the readings of the two gauges be plotted as ordinates and abscissas respectively, the resultant points when connected by a line will express the relation between the two gauges, or, as I have termed it, simply the gauge relation. But as the object of the investigation is to show the effect on the lower gauge of the same discharge which has acted on the upper one, it is evident that a time interval must be allowed between the readings at the two gauges. From a very careful study of the hydrographs, and from a comparison of all the series of simultaneous discharge measurements which have been made, it appears that for all portions of the stream as far down as Red River the rate of travel of discharge is about 75 miles in 24 hours at all stages of the river except dead low water and general overflow.

This statement, in view of the well-known variations, of velocity, seems paradoxical in the extreme, and I do not attempt to explain it. I simply state it as a fact borne out by all the evidence in our possession, and apparently correct to within the limits of error of the observations themselves. Therefore, in taking the readings of the lower gauge a time interval on this basis must be allowed, interpolated readings being used when the distance between the gauges varies from an even multiple of 75 miles.

When the records of two gauges between which no tributary enters are plotted in this way the points fall approximately on a straight line, the more careful the gauge readings the closer the agreement, and this straight line expresses the relation be-

tween the gauges. being more or less inclined in the ratio of their relative oscillations. When a tributary intervenes between the gauges the points will not fall on a straight line as before, as the values of the lower gauge are relatively larger by the varying volumes of the tributary. In this case the line of equal volumes or zero increment can only be determined when the values of discharge above and below the tributary and the discharge curve for one of the points are known. The method will be explained further on in discussing the data of 1884–'85, which first rendered these determinations possible.

Having the gauge relations determined it is an easy matter to transfer the standard curve to any point, graphically, by plotting the values of discharge for even feet on the one gauge to the equivalent readings on the other, or by substituting in the equation of the curve the value of one gauge expressed in terms of the other. In this manner the standard curve has been transferred from point to point and compared with all series of discharge measurements which have ever been made on the Mississippi River. An extended study of the gauge relations has shown that they are, as a rule, constant only in their inclination. Their absolute position frequently varies from year to year, and may in fact dó so several times in the same season. Where discharge measurements of different years have been compared the same discrepancies are noted as shown by the gauge relations and in the same direction; that is, the discharge curve of one year may not answer for another year unless its position be more or less shifted up or down. The data afforded by the gauge relations, although not so definite as those of discharge measurements, are of course much more extensive.

It has further been noted that in a series of discharge measurements, no matter how apparently scattered they may be, it is always possible to group them about a series of curves or trends which are parallel to the standard curve and either above or below it. All these phenomena are such as might be expected were the whole river bodily raised or depressed so as to change its plane of flow, the gauge remaining fixed in position. I have, therefore, for convenience designated the whole class of phenomena as "Changes of plane." Now, as these changes of plane from year to year and even during a single season amount often to several feet, that is to say, the zero of the discharge curve is raised or lowered by such amounts, a moment's reflection will show the hopelessness of determining discharge from gauge readings, unless some method is devised by which these changes of plane may be determined and allowed for. Further study and continued observation may enable this to be done, and it is well worth the effort. Meanwhile such general points as have been noted will be stated.

Setting aside the small changes which occur during the period of low water, and which are undoubtedly due to the action of bars, it appears that all the principal changes of plane occur at the mouths of the tributaries. The observations of 1884–'85 show also that, at least from Helena down, these changes wherever or however inaugurated are transmitted downstream from point to point according to the relation of the gauges. They are also cumulative, that is, to a change of plane starting at Helena may be added another at the mouth of White River, with further additions at the Yazoo and Red rivers, the final change of plane at Carrollton being the equivalent of the sum of the whole. I have very little doubt that these changes of plane may start at or near Cairo, but the breaks in the Point Pleasant series of 1884–'85 have rendered it as yet impossible to decide this question definitely. Another striking feature of these changes of plane is the length of time that they sometimes endure. As will be shown in some of the examples now laid before the Commission, their effect may last nearly a year, or nearly from one low water to another.

I will now call the attention of the Commission to certain plates which accompany this paper, and which afford the data for comparing the standard discharge curve with all recorded series of discharge measurements on the Lower Mississippi. The curve itself, with the observations from which it was computed, is shown on Plate 1.

Plate 2 gives the gauge relations of 1879 between Columbus–Point Pleasant, Columbus–Memphis, Point Pleasant–Fulton, Fulton–Memphis, and Memphis–Helena. Also the Columbus and Memphis hydrographs and the discharge measurements at those stations plotted to time.

Plates 3 and 4 give the variations to time of the 1884–'85 discharge data. For the fair lines drawn through the observed values of discharge to give the probable true sequence, values deduced from the curves of this year, shown on Plates 9 and 11, have been used.

Plate 5 gives the actual and equivalent gauge relations in 1884–'85 between Helena–Arkansas City, Arkansas City–Vicksburg, Arkansas City–Red River Landing, and Red River Landing–Carrollton. The equivalent gauge relations are the relations for equal volumes, in which the effects of tributary increment are eliminated. As an example of the method by which they are obtained the Helena–Arkansas City rela-

tion may be referred to. To obtain it we take the observed values of discharge at Arkansas City, and obtain from the curves holding at that time at Helena the gauge heights which correspond to these values. These gauge heights, plotted to the observed Arkansas City gauge heights, give the line of equal volumes or zero increment. It will be noted that several well-marked lines are indicated, these indicate changes of plane at Arkansas City not occurring at Helena, and are in the main due apparently to the effect of Arkansas and White rivers.

Plate 6 gives for 1884-'85 the hydrographs at the various observation stations.

Plate 7 gives the Columbus and Memphis discharge observations of 1879, and the Point Pleasant and Columbus observations of1884-'85. These observations are all plotted to gauge, and on the diagrams are shown the various probable positions of the standard curve.

Plate 8 shows, plotted to gauge, the Columbus discharge observations of 1858 and 1882; also the various probable positions of the standard curve.

Plate 9 gives the discharge observations at Helena in 1882 and 1884-'85, and also those at Arkansas City in 1884-'85. The positions of the standard curve are also shown. On the 1884-'85 Helena diagram these positions are assumed arbitrarily to fit what appear to be the principal changes of plane, but, from this point down, are transferred by the lines of equivalent gauge relation for the year. The supposed variation of discharge, while passing from one plane to another, is indicated by the oblique lines on the diagrams. The numbers give the numerical sequence of the discharge observations, and such corrections as are needed to make the observations fall on the assumed curves are indicated. As will be seen, they are small in amount.

Plate 10 gives similar information for Vicksburg in 1858 and 1884-'85, these latter observations being transferred up from Red River Landing.

Plate 11 gives similar information for Red River Landing in 1882 and 1884-'85.

Plate 12 gives similar information for Carrollton in 1851, 1880, 1883, and 1884-'85.

I think that an inspection of these plates will justify the assertion already made that the computed standard discharge curve gives the relation between gauge and discharge with sufficient accuracy. They also indicate the difficulties which beset the practical use of the curve obtained owing to changes of plane, and the main fact already alluded to that these changes of plane, to whatever cause due, are transmitted from point to point downstream. As the description of the methods used in making transfers, etc., has been necessarily a brief one, I append to this paper a full description and analysis of the process as applied to the 1884-'85 data from Helena to Carrollton, prepared by my assistant, Mr. Jas. A. Seddon, C. E., who has been associated with me in this work.

I will now pass to the main subject of this paper, viz: The effect of Red River in enhancing flood heights on the Lower River.

It has been already stated in this paper that changes of plane occur mainly at the mouths of tributaries. This is most markedly the case at the mouth of the Red River and attracted attention at an early stage of these investigations. No explanation suggested itself, however, until the data, for 1884-'85 were under investigation. In December and January of 1884-'85 a very abrupt change of plane took place, as shown on both the gauge relation and the discharge curve, and this change was found to coincide with a considerable rise in Red River, the Mississippi being at quite a low stage. This change of plane or elevation of the zero of the discharge curve amounted to 5.8 feet, and inspection of Plate 8 will show that this elevation was substantially retained throughout the season, and on it were superposed the changes of plane amounting to 3.35 feet more which were transmitted down from Helena and Arkansas City. The gauge relation with Vicksburg shows that it was not eliminated until the low water of 1885 had fairly set in so that it lasted through a period of about 8 months. As this case suggested that there might be a connection between these changes of plane and floods in the Red River, an investigation was made of all the data at our command. The discharge data was too meager for the purpose so the gauge records were used instead. As already stated in general terms the relation between two gauges when no increment intervenes is a straight line, but when an increment is present the gauge heights at the lower point are set over from the line of equal volume or zero increment by the amount due to the volume of the increment plus any change of plane which may occur. In this case the relations Vicksburg-Red River Landing are used so as to eliminate any effect due to the Yazoo. The inclination of the line of zero increment was established by the 1884-'85 observations, but its absolute position for other years can not be fixed with certainty.

Plates 13 and 14 give all known Vicksburg-Red River Landing actual gauge relations from 1858 to 1888, the only omission being the year 1877-'78 of which the gauge records are incomplete. On each of these relations is shown a line marked "standard" which gives the line of zero increment in an arbitrary position, but one common to all the diagrams. A second line marked "primary plane of year" indicates the probable position of this line for the year in question. An inspection of these diagrams shows very great deviations from the line of zero increment, deviations

which must either indicate enormous discharges from Red River or very great changes of plane. We can get from the Alexandria discharge curve the volume of Red River at that point, but even if this entire volume be taken as issuing from Old River it will not begin to account for the deviations noted, and we are certain that no such discharges do take place owing to the draft made by the Atchafalaya, which more than balances any increment received from the Black and Ouachita, which enter the Red below Alexandria. We know moreover from the two series of discharge measurements in 1881–'82 and 1884–'85 that there *are* great changes of plane, hence it seems legitimate to infer that the larger portion of the deviations noted are due to this cause. A careful analysis of the diagrams has also shown that these changes of plane essentially coincide with rises in Red River as shown by the Alexandria gauge, and which in turn probably always indicate a discharge from Old River into the Mississippi. The most marked effect usually accompanies the first decided rise after the summer and fall low water as has already been spoken of as occurring in December and January of 1884–'85. In that instance the measured outflow from Old River was 70,000 cubic feet at its maximum. This increment was accompanied by a rise in the zero of the Red River discharge curve (see plate 11) amounting to 5.8 feet. It may not be amiss to mention here that an increment of 308,000 cubic feet, at the mouth of White River this same season was accompanied by a change in the plane of discharge at Arkansas City of 1.6 feet only. On many of the diagrams will also be noted a large change of plane or increment effect occurring at or near the highest stage. This was very marked in 1874 and again in 1882. In the former year we have no definite information as to the volume of water which entered the Mississippi from Red River, but the Red River Landing gauge rose 9.2 feet while the Vicksburg gauge rose but 3 feet. The rise at Red River Landing corresponding to the Vicksburg rise should have been 2.3 feet, leaving 6.9 feet rise, at a stage above 38 feet, due to increment from Red River or change of plane, or both combined. In 1882 we find a similar rise above the 40-foot stage amounting at Red River Landing to 6.6 feet while at Vicksburg the rise was only 1.8 feet. This should have caused a rise at Red River Landing of 1.4 feet, a difference of 5.2 feet due to the Red River increment and to change of plane. During this year the discharges at Red River Landing were measured, and an examination of the diagram (plate 11) shows that during the period considered a change of plane took place amounting to not less than 2.8 feet. It seems therefore safe to infer that in 1874 the change of plane was at least as great, if not greater. Besides these large changes of plane many minor ones occur, but all show the same feature of persistent and cumulative effect, so that the aggregate in some years is enormous.

That these changes of plane are not due to effects produced by the Mississippi independent of Red River is not so susceptible of proof, but the year 1886–'87 furnishes some evidence in that direction. In that year Red River was very low for an unusually long period. As will be noted on the diagram for that year the Mississippi at Red River Landing rose to an elevation of 32 feet on the gauge with a deviation from the primary plane of the year of less than 2 feet. Then came a rise in Red River followed by a decided change of plane in the Mississippi at Red River Landing. In the succeeding year we have an inflow from Red River occurring in December, at a time when the Mississippi was at a very low stage, 6 feet on the Red River Landing gauge. This inflow was accompanied by a change of plane of between 3 and 4 feet which persisted throughout the season. That these so-called changes of plane are genuine local engorgements is plainly shown by the effect at Natchez, 65 miles above Red River. The gauge relations between Vicksburg and this place show that for all except low stages of water, changes of plane occur at Natchez of the same character as those at Red River Landing, but less in amount. They, however, occur at Natchez on an average about 2 days *later* than at Red River Landing. This shows conclusively that they are genuine backwater effects, for if they occurred from local causes at Natchez they should appear there *earlier* than at Red River Landing.

There certainly can be nothing in the character of the channel below Red River to account for these phenomena as it is well known to present most unusual facilities for discharge. This is evidenced by the small slope and small gauge oscillation. It is also very strikingly shown by the rate of transmission of discharge which, as before stated, is 75 miles in 24 hours for points above Red River. Between Red River and Carrollton this rate is 192 miles in 24 hours, some 2½ times as great as for points above. Moreover, these changes of plane do not accompany increase of volume solely, as they would in case of an obstructed channel, but only increase of volume from one special source, viz., Red River. The conclusion seems therefore inevitable that in some way the discharge from this tributary is not in harmony with that of the main stream and by diminishing its relative mean velocity changes the ratio of discharge to gauge in the manner noted. This is the only explanation which suggests itself to me to account for so singular a phenomenon, as a matter of fact the water from Red River seems to partly fill the channel as so much mud or sand would

do, and to remain there, so that the water coming from above is forced to climb on top of it in order to continue on its way to the sea.

The effect of these abnormal elevations at Red River has a very important bearing on the lower river. The gauge relation Red River Landing–Carrollton is the most remarkably constant of any yet noted. A single plate, No. 15, gives the relations for all years in which records have been kept from 1851 to 1888. The gauge relation for equal volumes was determined in the manner already described from the 1884–'85 observations, (see plate 5) and this line is plotted as a standard on all the yearly diagrams. It will be noted that the only divergences of moment are in years when crevasses existed between the two stations, giving abnormally low Carrollton readings while they were active. These gauge relations show the intimate bond of union between the two gauges, and the 1884–'85 discharge observations (plate 12) show how faithfully the Red River Landing changes of plane are reproduced at the lower station. Therefore if Red River Landing is abnormally high, Carrollton is also abnormally high in the regular ratio, and if by any means the gauge heights at Red River Landing could be reduced then the Carrollton gauge heights ought to come down in the same ratio.

In order to show more clearly what these statements mean some tables are given.

Table No. 1 is deduced from the Vicksburg-Red River Landing gauge relations, and gives the total deviation at the maximum Red River Landing stage from the standard of the year for each year of the series, due to the influence of Red River, as also the equivalent deviation for Carrollton.

Table No. 2 gives for the same years the elevations corresponding to the Vicksburg maxima which would have been reached at Red River and Carrollton had the standard plane of the year held throughout.

Table No. 3 gives in parallel columns the actual maxima for each year at Vicksburg, Red River Landing, and Carrollton, together with the heights that would have been reached in each case if all the levees had been up from Vicksburg to Carrollton; in the one case with Red River still entering the Mississippi, in the other with the Red River shut out and its influence eliminated.

The last two tables depend on the gauge relations and the actual Vicksburg maxima for the years indicated.

In all these tables it must be noted that the total effect of Red River is given, viz, that due not only to change of plane, but also to regular effect of increment. Any attempt to separate the two in the absence of actual measurements would be a very doubtful process, and of course if Red River were excluded both effects would be canceled.

These tables show in a general way that in every year noted there is an abnormal elevation of the plane of flow at extreme stages both at Carrollton and Red River. At the latter place this abnormal elevation has amounted to as much as 13 feet, at the former place to 5.4 feet. They also show that if the levee system had been perfect from Vicksburg to Carrollton, the actual mean maximum gauge reading at Red River Landing would have been increased 0.43 feet, and at Carrollton 1.11 feet, while under the same condition, but with Red River shut out, the actual mean maximum at Red River Landing would have been reduced 7.29 feet, and at Carrollton, 2.09 feet. Consequently, with the levees all up the difference in mean maxima between the conditions with Red River open and closed would amount to 7.72 feet at Red River Landing, and at Carrollton to 3.20 feet, the actual maximum differences being 13 feet for Red River and 5.4 feet for Carrollton.

These are very large figures and their importance as regards the levee problem can hardly be too highly estimated. To be able to bring down the flood levels below Vicksburg to such an extent, especially in view of the fact that larger discharges than ever known must in the near future be provided for in that section of the river, would go a long way towards insuring the permanent redemption of all lower Louisiana from overflow.

If the facts herein cited are sufficient, as I myself think they are, to show that Red River, instead of being at best a doubtful friend, is really a most treacherous enemy, then I think it the imperative duty of the Commission to reconsider their plans for this portion of the river, to divorce the Red River permanently from the Mississippi, and to provide at some point a canal connection between the two streams.

Very respectfully, your obedient servant,

CHAS. R. SUTER,
Lieut. Col. of Engineers,
Member Mississippi River Commission.

Gen. C. B. COMSTOCK,
President Mississippi River Commission.

TABLE No. 1.

Year.	Elevation of primary plane of year above standard.	Red River Landing. Maximum stage. Date.	Red River Landing. Maximum stage. Gauge reading.	Red River Landing. Rise of plane above primary elevation.	Red River Landing. Normal maximum gauge reading or maximum less rise plane.	Carrollton equivalent of Red River Landing rise of plane.
1871–'72	4.8	May 5	39.4	6.7	32.7	2.8
1872–'73	2.0	June 2	39.0	8.2	30.8	3.4
1873–'74	2.8	Apr. 16	47.0	13.0	34.0	5.4
1874–'75	2.5	May 2	40.4	7.9	32.5	3.2
1875–'76	3.2	May 15	45.4	10.2	35.2	4.2
1876–'77	1.8	June 1	40.5	9.9	30.6	4.1
1877–'78 *	....	....	....	....	....	....
1878–'79	4.3	Feb. 19	35.9	3.8	32.1	1.6
1879–'80	†0.8	Apr. 21	44.0	†12.8	†31.2	†5.3
1880–'81	3.5	Apr. 6	40.1	7.3	32.8	3.0
1881–'82	4.2	Mar. 27	48.5	10.1	38.4	4.2
1882–'83	5.0	Apr. 9	45.2	9.0	36.2	3.7
1883–'84	5.0	Mar. 29	47.3	7.5	39.8	3.1
1884–'85	5.9	Feb. 2	41.9	5.9	36.0	2.4
1885–'86	6.2	May 29	41.9	5.8	36.1	2.4
1886–'87	5.6	Apr. 5 Apr. 8‡	42.9 43.0	5.7	37.3	2.3
1887–'88	5.6	Apr. 30	41.7	4.7	37.0	1.9

* Gauge readings at Red River Landing missing.
† The primary plane of this year is thought to be too low, and hence all deduced values unreliable, probably from error in the Vicksburg gauge records, which are very incomplete.
‡ By this date the Vicksburg gauge has fallen considerably and the plane would show abnormally high from increment.

TABLE No. 2.

Year.	Vicksburg maximum gauge reading.	Red River Landing equivalent on primary plane of year.	Actual maximum gauge reading at Red River Landing.	Actual Red River Landing gauge above equivalent gauge.	Carrollton equivalent gauge for Red River Landing equivalent.	Actual maximum gauge reading at Carrollton.	Actual Carrollton gauge above equivalent gauge.
1871–'72	39.5	32.7	39.4	6.7	10.3	12.3	2.0
1872–'73	40.6	30.8	39.0	8.2	9.6	12.9	3.3
1873–'74	45.7	35.5	47.0	11.5	11.5	15.9	4.4
1874–'75	43.0	33.1	40.4	7.3	10.5	11.3	0.8
1875–'76	44.9	35.3	45.4	10.1	11.4	12.7	1.3
1876–'77	41.6	31.3	40.5	9.2	9.8	11.1	1.3
1877–'78*	40.9	....	....	....	....	11.3	....
1878–'79	39.4	32.1	35.9	3.8	10.1	10.8	0.7
1879–'80	43.1	31.5	44.0	12.5	9.9	14.2	4.3
1880–'81	41.8	33.2	40.1	6.9	10.5	12.5	2.0
1881–'82	48.7	39.2	48.5	9.3	13.0	14.9	1.9
1882–'83	43.8	36.2	45.2	9.0	11.8	15.4	3.6
1883–'84	49.0	40.2	47.3	7.1	13.4	15.6	2.2
1884–'85	42.4	36.0	41.9	5.9	11.7	13.5	1.8
1885–'86	44.1	37.7	41.9	4.2	12.4	13.8	1.4
1886–'87	44.7	37.5	43.0	5.5	12.3	14.5	2.2
1887–'88	44.2	37.1	41.7	4.6	12.1	14.3	2.2

* Red River Landing gauge readings missing.

TABLE No. 3.

Year.	Vicksburg maximum gauge reading.	Red River Landing maximum gauge.			Carrollton maximum gauge.		
		Actual reading.	Deduced reading for levees complete from Vicksburg.		Actual reading.	Deduced reading for levees complete from Vicksburg.	
			Red River open.	Red River closed.		Red River open.	Red River closed.
1871–'72	39.5	39.4	39.4	32.7	12.3	13.1	10.3
1872–'73	40.6	39.0	39.0	30.8	12.9	12.9	9.6
1873–'74	45.7	47.0	48.5	35.5	15.9	16.9	11.5
1874–'75	43.0	40.4	41.0	33.1	11.3	13.8	10.5
1875–'76	44.9	45.4	45.5	35.3	12.7	15.6	11.4
1876–'77	41.6	40.5	41.2	31.3	11.1	13.9	9.8
1877–'78	*40.9	...	...	...	*11.3	...	...
1878–'79	39.4	35.9	35.9	32.1	10.8	11.7	10.1
1879–'80	*43.1	*44.0	*44.3	*31.5	*14.2	*15.1	*9.9
1880–'81	41.8	40.1	40.5	33.2	12.5	13.6	10.5
1881–'82	48.7	48.5	49.3	39.2	14.9	17.2	13.0
1882–'83	43.8	45.2	45.2	36.2	15.4	15.5	11.8
1883–'84	49.0	47.3	47.7	40.2	15.6	16.5	13.4
1884–'85	42.4	41.9	41.9	36.0	13.5	14.1	11.7
1885–'86	44.1	41.9	43.5	37.7	13.8	14.8	12.4
1886–'87	44.7	43.0	43.2	37.5	14.5	14.7	12.3
1887–'88	44.2	41.7	41.8	37.1	14.3	14.1	12.1
Sum	653.4	637.2	643.6	527.9	201.5	218.4	170.4
Mean	43.56	42.48	42.91	35.19	13.45	14.56	11.36

* Values marked * are omitted from the sum and mean values for reasons noted in tabulation 1.

REPORT OF MR. JAMES A. SEDDON, ASSISTANT ENGINEER, UPON THE INVESTIGATION OF THE MISSISSIPPI RIVER DISCHARGE DATA OF 1884–'85.

ST. LOUIS, MO., *July 31, 1888.*

COLONEL: I have the honor to make the following report on the investigation of the Mississippi River discharge data 1884–'85.

The observations at Point Pleasant were too scattering for anything like a thorough investigation, so that the study was practically commenced at Helena, with the results of prior investigation assumed as known, viz: That there was a given normal variation of discharge to gauge reading at Helena represented by a given curve when gauge readings were taken as ordinates and the corresponding values of discharge as abscissas, and that there were abnormal periods during which the variation of discharge with gauge passed from this curve in one position on gauge to the same curve shifted to a position either higher or lower on the gauge scale, so that a series of discharge observations, when platted to their accompanying gauge readings, should give a series of curves parallel in the direction of gauge and joined by irregular lines.

Some of the terms used in this report will be here defined. The period in which the discharges vary about on one of these curves is called a "normal period," and the curve a "normal curve." The daily values of discharge, scaled or calculated from these curves for the daily gauge readings, is called a "sequence of discharge," and the variation of discharge, where a change from one normal curve to another takes place, is called a "change of plane."

In the investigation of the 1884–'85 data Helena was taken up first, and the Helena normal curves were adjusted to their various planes, so that when the sequence of discharge at Helena was computed this sequence would agree as near as possible with the actual discharge observations taken there. In this agreement of the sequence with the observed discharges use was made not only of the Helena discharges, but also of those measured at Point Pleasant, with a 3 days' interval allowed as the time for a value of discharge at Point Pleasant to reach Helena. This comparison is shown on Plate 3. The Helena discharge values are there plotted as ⊙, and the Point Pleasant as a △, and the fair line through them is the computed sequence of discharge at Helena. The various planes or normal curves holding, with the time through which each curve holds, and the periods of transition are shown diagrammatically at the top; also the hydrograph of the St. Francis River, the principal

tributary between Point Pleasant and Helena, is given. On Plate 9 is shown the Helena discharge observations plotted to gauge with the normal curves of the period drawn through them. The direction of change of plane is indicated by arrows on the slant lines joining the curves and the principal corrections assumed for individual observations to bring them on the curves are indicated.

Having completed this primary investigation for Helena, in the main every other value of discharge in the whole river rests upon it, but as the steps from point to point down are with minor exceptions, exactly similar, it will be sufficient to consider in full the investigation of the reach Helena to Arkansas City, and note minor differences in the investigation of other reaches.

In the investigation of the reach Helena to Arkansas City, the above Helena sequence and changes of plane are plotted with Arkansas City data for comparison (see Plate 3); on this points ⊙ are the Arkansas City measured discharges plotted with an interval of 1¼ days from Helena. A few of these Arkansas City observations that were clearly out of sequence by considerable amounts were primarily corrected to be in approximate sequence. The corrected values of these few observations are shown as △ on the respective days. The observed gauge readings and values of discharge at Arkansas City were then tabulated through the period, small gaps in the observed discharge values being filled by interpolation, and with this tabulation was indicated the periods of the respective normal curves at Helena. During the period, then, that a given curve held at Helena, a Helena gauge reading could be scaled on this curve for the Arkansas City value of discharge, and this Helena gauge reading would be the reading that would have been observed at Helena if the same value of discharge had passed there as was found at Arkansas City. Such a gauge reading at Helena is called the equivalent of the Arkansas City observed gauge reading, for they both correspond at that time to the same value of discharge at Helena by the law that is holding there in the variation of discharge with gauge, and at Arkansas City observed with the discharge there, in whatever law or absence of law that may be holding them in the variation of discharge with gauge at that point. These Helena equivalent gauge heights were determined for the whole period on the respective Helena normal curves, except during the short interval of change of plane at Helena.

The observed Arkansas City gauge readings were plotted as abscissas to the equivalent Helena gauge heights as ordinates, shown on Plate 5. Time is indicated at intervals by dates to the points of the Arkansas City gauge readings at intervals and intermediate times by the numbers of the Arkansas City discharge observations at such times. The short periods of change of plane at Helena, when the Helena equivalent gauge heights could not be deduced, are shown dashed. This is called the "equivalent gauge relation" and, simply for comparison, is plotted with it the "actual gauge relation" or observed gauge readings at both points, the time interval being allowed.

We see on this equivalent gauge relation that the period from 1 (October 13) to 12 and again from 58 to 76 is very closely expressed by line (1), and again from 81 to April 11, the end of the observations, by line (3), line (3) being of the same inclination as line (1), but with values uniformly 1.6 feet larger on the Arkansas City gauge scale. Omitting for the present the consideration of other periods, and taking line (1) as expressing the true law of relation between Helena and Arkansas City equivalent gauge heights for the time between observations 58 and 76, and remembering that these equivalent gauge heights represent equal values of discharge at Helena and Arkansas City, we may substitute for the Helena gauge heights in the law of variation of discharge to gauge there the values of the corresponding Arkansas City gauge heights on this line (1), and this will give the law of variation of discharge to gauge occurring at Arkansas City during this time. This is called a transfer by a line of gauge relations. While a normal curve is holding at Helena, this line gives us the fact that a like curve is holding at Arkansas City, the only difference in the curves being that the gauge scale is changed at Arkansas City in a ratio given by the inclination of this line; this ratio is 1′ on Helena gauge equals 0.944 foot on Arkansas City gauge. Also, where there is a change of plane at Helena, as there is of + 1.5 feet between points 69 and 70, we have the fact that there is a change -f plane at Arkansas City in the same equivalent time and the same in amount hen expressed in the Arkansas City equivalent gauge scale, or in absolute amount qual 1.5 feet × 0.944 = 1.416 feet. From this it can hardly be doubted that the lange of plane at Helena between points 69 and 70, is in no way a local phenomion, but passes down with the flood at Helena to Arkansas City, as close as we can etermine, unchanged in form and in the regular interval of 1¼ days.

In the period between points 76 and 81, or of transition from line (1) to line (3), re see that a change of + 1.6 feet (Arkansas City gauge) occurs *between* Helena and rkansas City as an effect, to be added to those transmitted down from Helena, or iat after point 81 the Arkansas City gauge height for a given Helena gauge height, id hence for a given value of discharge on whatever normal curve be taken at Hela, is uniformly of 1.6 feet greater value than it was during the period of line (1).

Following point 81 to the end of the observations, all the equivalent gauge heights falling on line (3) show that the variations of discharge to gauge at Arkansas City follow identically the Helena variations as in line (1), though raised as a whole in addition this 1.6 feet on the Arkansas City gauge. The seven periods of normal variation being gotten by simply substituting for the Helena gauge the values of the Arkansas City gauge scaled on line (3), and the six changes of plane at Helena being apparently identically transmitted down to Arkansas City. There is one exception here, however, to this identity in transmission of the change of plane from Helena to Arkansas City. It is seen that a change of plane—1.1 feet (Helena gauge) occurs between points 89 and 90, while the equivalent gauge points for 90 and the day following are found about 1.1 feet (Helena gauge) below line (3) and pass back to line (3) in the next 2 days. This shows that the fall of plane that occurred then at Arkansas City was several days later than the interval of 1½ days in its passage down from Helena. It has necessarily taken place at Arkansas City when the equivalent gauge heights plot on line (3), but, for the points 90 and the day following, it appears evident that the fall of plane at Helena has given Helena equivalent gauge heights too low for the Arkansas City observed gauge heights by the amount of this fall of plane at Helena.

Lines (1) and (3) can be taken very confidently as representing with great accuracy the law of relation between equivalent gauge heights at Helena and Arkansas City during their respective periods, for the divergence of the plotted points from these lines is very fully within the effect of accidental errors of the Arkansas City discharge observations, and, in fact, this shows a degree of precision in the bulk of the observations that it was before hardly thought could be attained.

Beyond the periods covered by lines (1) and (3) there is the low-water phenomena, which is in very striking contrast with the above. Between points 12 and 13 there is a fall of plane at Helena of 0.7 foot (Helena gauge), and corresponding to this there is no fall of plane at Arkansas City, for the equivalent gauge points from 13 to 25 plot about on (A), which is just 0.7 foot lower on the Helena gauge. That is, between 12 and 13 we have passed to a curve 0.7 foot lower in scaling the Helena equivalent gauge heights, and we find these plotting to the observed Arkansas City gauge heights, 0.7 foot (Helena gauge), lower at 13 and the points following, than they did at 12; hence the law of variation of discharge to gauge at Arkansas City is continuous through the period, and the shifting of the equivalent gauge points is a result of the independent change of plane (− 0.7 foot) at Helena.

Again, between points 25 and 35 there is a slow fall of plane at Arkansas City to line (2) that is independent of any change of plane at Helena, as in the case of rise of plane from lines (1) to (3) before considered. From 35 to 1 day after 50, line (2) is taken as representing the true variation of equivalent gauge heights, though some of the points diverge here considerably from it. This is thought to be legitimate here, for at this stage quite small errors in discharge may cause considerable errors in gauge.

From 1 day after 50 to 53 there is the rise of plane at Helena of 0.7 feet and following it the period (B). This as (A) is not a change of plane at Arkansas City, the period (B) being simply a shifting of line (2) to a position of 0.7 feet higher on the Helena gauge by the change of plane at Helena + 0.7 feet. From 56 to 58 we have the rise of plane at Arkansas City to line (1), independent of any rise at Helena, and following 58 the changes before considered. This change of plane 56 to 58 was finally taken as commencing between 55 and 56, for it then gave a fairer sequence of discharge at Arkansas City.

The contrast of this low-water period with the other is very striking. In it the changes of plane occur totally independently at the two points, Helena and Arkansas City, and hence, by inference, are local phenomena, while above the low-water stage all changes of plane at Helena are apparently identically transmitted down to Arkansas City, and hence, by inference, are phenomena, general to all points, or impressed on the flood in its passage down the river. The independence of changes of plane at low water is thought to be due to these changes being here results of scour of low-water channels through bars and local shiftings of the low-water slope from pool to bar, and therefore of a nature totally different from the changes of plane that are general and that occur at the higher stages. In fact, it may readily be supposed that there are places where no true normal curve exists during the low-water period.

In what has preceded the equivalent gauge relation has been discussed in specific periods, but, to avoid unnecessary explanations in the future, it may be well here to generalize this discussion as follows: When the equivalent gauge heights plot on one straight line, the variations of discharge to gauge are exactly similar at the upper and lower points; they are simply the same variation, plotted to gauge scales, having a constant ratio, given by the inclination of this line; hence normal curves at the upper are normal curves at the lower point and changes of plane at the upper are the same changes of plane at the lower point. When the equivalent gauge

heights, plotted, show a shifting from one line to another of the same inclination such a period of shifting is a change of plane that is not common to the two points. From the gauge relation alone we can not say where this change occurs. It may be a change at the lower point that was not found at the upper, as the period from 76 to 81 (see the Helena-Arkansas City equivalent gauge relations on Plate 5), or it may be a change of plane at the upper point that was not found at the lower, as the change from 12 to 13, or it may be any combination of changes of plane at both points, with excess at one a given amount over that at the other. But, with the actual changes of plane at one of the points and the equivalent gauge relation given, the actual changes at the other point may be at once determined. Say the changes of plane at the upper point are known and expressed in the equivalent ratio for the lower point (in the Helena-Arkansas City case = $\pm$ Helena change of plane multiplied by 0.944), and that the changes from time to time of the equivalent gauge relation are given in terms of $\pm$ change on lower gauge, then the actual changes of plane at the lower point are simply the algebraic sum of these two, or the normal curve at the lower point, at any time, is simply the normal curve of that time at the upper point transferred by the line of the equivalent gauge relation of that time.

Above the Helena-Arkansas City data of Plate 3 there has been represented diagrammatically the changes of plane at Helena. Under this is a diagram of the changes in terms of the lower gauge of the equivalent gauge relation shown on Plate 5, below is a diagram of the resulting normal curves and periods of change of plane at Arkansas City in terms of the Arkansas City gauge values. On Plate 9 are shown these curves and changes of plane drawn among the Arkansas City discharge observations, plotted to gauge.

Finally, an Arkansas City sequence of discharge equivalent in time to the Helena sequence (1¼ days interval) was scaled for the Arkansas City gauge readings on the above discharge curves, and is shown, drawn as a fair line, among the Arkansas City discharge observations, plotted on Plate 3. The differences between the Helena and Arkansas City sequences give the increments entering the Mississippi between these points. These are plotted below as also the combined discharge of the Arkansas and White rivers, scaled from discharge curves, calculated from the 1879 observations on those streams. The comparison of the two shows how a flood out of the tributaries is retarded in its entrance by a rise in the main river.

In scaling the sequence of discharge there was primarily no certainty of the exact values of discharge, either at Helena or Arkansas City, during the periods of change of plane at these points. However, after the equivalent gauge relation had been determined, all periods of coincident change of plane could be adjusted with greater accuracy, for then approximate values of discharge might be taken on either the Helena or Arkansas City sequence and the values of the other point deduced. These values at the two points would be practically exactly true in their difference and they might then be both put a given amount larger or smaller, so as to best agree with the observations at the two points. A single instance of this will be sufficient to make the method clear. Taking the change of plane, January 31–February 1, the values of discharge may be scaled on the Arkansas City sequence and the corresponding Helena discharges deduced as follows:

Date.	Arkansas City.		Helena gauge.	Helena, equivalent of Arkansas City gauge on line (3).	Δ G. or Helena equivalent less actual gauge reading.	ΔQ. or discharge increment corresponding to Δ G.	Helena discharge or Arkansas City discharge less Δ Q.
	Gauge.	Discharge.					
Jan. 31	41.7	1,082	40.50	42.90	2.40	86	996
Feb. 1	41.4	1,055	39.75	42.55	2.80	110	945

(Values of discharge are given in thousands of cubic feet per second.)

And if the Helena values of discharge had shown any need of further adjustment, the values at both Helena and Arkansas City could have been changed, keeping the above values of ΔQ constant. By this method the sequence of discharge during all coincident changes of plane were adjusted.

In addition to the above plates the following tabulations are presented, giving the outline of the work in this investigation of the Helena-Arkansas City data.

Tabulation I gives the coördinates of the Helena normal curves, as they were assumed, and the resulting coördinates of the Arkansas City normal curves as they were finally deduced. It will be seen in this that the values of discharge have been taken common to all the curves, while the various corresponding values of gauge have been calculated. This is the best method where an actual calculation of the points is made, for in that case the various gauge values of each curve may be cal-

culated by the addition of a constant difference, while if the various discharge values of a curve were to be calculated the process would be much longer.

Tabulation II gives the steps in the deduction of the Helena-Arkansas City equivalent gauge heights. In the column of Arkansas City discharge those values marked † are values either interpolated between the actual observation, or observations with considerable errors that were primarily corrected, so as to be in approximate sequence, as before noted; all others are the Arkansas City observed discharge values.

Tabulation III gives the values of the Helena and Arkansas City sequences, the increments between Helena and Arkansas City, with the combined discharge of the White and Arkansas rivers. In these last the interval has been taken as 1 day from Pine Bluff to the mouth of White River on the Mississippi or Pine Bluff dates equal Helena dates.

The unit for values of discharge in all the above tabulations, as well as those that will follow, is taken as 1,000 cubic feet per second.

A similar comparison of the Arkansas City Red River Landing data is shown on Plates 4, 5, and 11, and Tabulations IV, V, VI give the outline of the work. After what has preceded a few notes will be all that is needed of explanation.

The change of plane at Arkansas City, November 14 to 24, is only taken as from 14 to 20 at Red River Landing, as seen in the Red River Landing sequence of discharge, for this is a low-water phenomena, and is not thought to be necessarily coincident at the two points. Again in the change of plane, January 10–11, the exact transmission of the Arkansas City plane is not taken, as this would make the Red River Landing sequence irregular. It is not thought that this is sufficient to prove that the change of plane was not exactly transmitted, for the time of the change of plane at Arkansas City can hardly be fixed so exactly as not to possibly overlap one day in transmission to Red River Landing; March 23 is also taken as a similar case of overlapping. These two cases are shown on the Red River Landing plotted sequence as dotted lines.

Tabulation IV gives the deduction of the Arkansas City-Red River Landing equivalent gauge heights.

Tabulation V gives the Red River Landing normal curves, resulting from the Arkansas City curves, and the equivalent gauge relation. It will be noticed that though essentially the same for the Arkansas City-Red River Landing reach, as Tabulation I was for the Helena-Arkansas City reach, it is yet very different in form. This arose from the fact that it was thought that, from Arkansas City down, no appreciable error would be introduced into the transfer by scaling the discharge values on the upper normal curves, in which case it is most convenient to scale them for even feet, and then calculate the lower gauge equivalents of these even feet on the various lines of the equivalent gauge relation, then, as before stated, obtain the lower normal curves of each period by plotting the values of discharge belonging to the upper normal curve of that period to the lower gauge equivalents on the line of the period. This method has been followed for all transfers below Arkansas City.

Tabulation VI gives the Arkansas City and Red River Landing sequence of discharge with the increments between the points.

A similar comparison of the Red River Landing and Carrollton data is shown on Plates 4, 5, and 12, and Tabulations VII, VIII give the outline of the work.

In all that has preceded, it has been assumed that the true stage was closely represented by the observed gauge readings, or that there was very little error in this observation in comparison with the error of the discharge observation. The Carrollton hydrographs, from the regular gauge records and from the readings of the observation party, plotted on Plate 4, show that this assumption can not be made at Carrollton, for there is very evidently an erratic variation to time of the Carrollton gauge readings and probably, also, sharp oscillations, for the two readings of the same date sometimes diverge considerably. It may be considered that elevation of Gulf tide plays a part in this at the low stages, for the average low water at Carrollton is not more than about one-half foot above mean Gulf tide, but is difficult to see how this may cut much of a figure at the high stages. The irregularity appears not to be confined to the low stages, and in default of any other explanation it is supposed to be due to tide and wind effects, though the wind effect is not apparent in the wind data given with the discharge observations.

Whatever the cause of this irregularity may be, it certainly renders very questionable the use of the Carrollton gauge reading as the measure of true stage at Carrollton, for it is hardly probable that the discharge would vary in a smooth sequence to time down to Red River Landing and change to an irregulor sequence between Red River Landing and Carrollton, which would be the case if the true discharge were taken as being given on a curve by the Carrollton gauge readings. As one of the many instances, observations Nos. 7, 8, 9, 10 show a very smooth variation of discharge to time, and agree very closely with what we would expect from the Red River Landing discharge in the equivalent period, and yet, as may be seen on Plate 12, they plot to gauge with considerable irregularity.

This uncertainty of the true stage at Carrollton appears to amount to something like one-half foot, and its existence must be borne in mind in considering the equivalent gauge relation and in the points of discharge plotted to gauge. At times not only must a point in error have a correction in the direction of discharge, but also in the direction of gauge. The special consideration of the period covering observations 63, 64, 65, will make this more clear. 63 is clearly in error in its discharge value, as shown by the discharge sequence, so that a discharge correction is given it that brings it more in harmony; also, on the hydrograph, it would appear that the more probable variation of true stage was represented by the dotted line, so that 63 would also have a gauge correction of about + 0.6 feet; 64 has the gauge correction alone, and 65 has no gauge correction, but, as compared with the Red River Landing discharge, its discharge value is probably too large. These points are therefore corrected on Plates 5 and 12, as shown by the arrows.

In the above case the corrections are rather fairly indicated by the data, and without attempting a minute investigation of each point, it is thought that this double uncertainty in the value of discharge and in the true stage at Carrollton is sufficient to account for the irregularities found. For the same cause, also, the sequence of discharge at Carrollton could not be computed.

Tabulation VII presents the deduction of the equivalent gauge relation. In this, only points of measured discharge at Carrollton are taken and the few that were corrected had only such corrections as were clearly shown by the sequence; where it was uncertain the points were omitted. Tabulation VIII gives the Carrollton normal curves.

The discharge observations, measured at Warrenton, were originally so discordant that no confidence could be placed in them, and though the final revision improved the appearance of the data, it was still thought best not to use them. As it was desirable, however, to obtain a normal curve for Vicksburg, approximate Vicksburg values of discharge were obtained from the Arkansas City, Red River Landing, and Old River discharges.

As seen on Plate 4, the difference between the Arkansas City and Red River Landing discharges to December 13 are very close to the escape from the Mississippi through Old River, so that we may very confidently take the Vicksburg discharge as essentially the same as that at Arkansas City, the discrepancy in the first 10 days being assumed due to error in the Old River observations. From December 13 on there is seen to be a material increment to the Mississippi between Arkansas City and the mouth of Old River; probably the greater part of this increment enters the Mississippi at the mouth of the Yazoo, above Vicksburg, so that Red River Landing discharge, less Old River discharge, should in the main approximate closely the Vicksburg discharge.

These have been taken for the Vicksburg discharges and the reach Arkansas City-Vicksburg considered in a manner similar to the others. The gauge relation is shown on Plate 5 and curves on Plate 10, and tabulations IX, X give the outline of the work.

In this work the values of discharge in the final sequences at the other points were used, and, as they are assumed to be the true values of discharge, it may be well to consider what errors remain in the Vicksburg discharges so deduced. First, there are the errors in the Old River discharge observations, and at times these are rather scattering, as shown on Plate 4, with the sequence sketched through them that was arbitrarily taken as giving the Old River discharge for each day. Second, whatever increment enters the Mississippi between Vicksburg and Red River Landing, by that amount the deduced Vicksburg discharges will be too large, and there are times where this has undoubtedly distorted the equivalent gauge relation and put points off the true curve. An instance will be sufficient. Between observations No. 66 and 68 the Arkansas City deduced gauge heights are too large (see Arkansas City-Vicksburg equivalent gauge relation on Plate 5). Also observation 67 plots with a discharge value decidedly larger than the curve value of the period (see Plate 10). It is seen by the hydrographs that this just about coincides in time with a sharp swell in the Yazoo and Red Rivers, and as the same rains that caused these rises should cause contributions from the left bank tributaries between Vicksburg and Red River Landing, it is very clear that the above irregularities are due to the error in the method of deducing the Vicksburg discharge. Finally any error in the Vicksburg gauge reading would cause irregularities. The scattering of points in the equivalent gauge relation and in discharge, plotted to gauge, are thought to lie within these causes of error.

As after observation No. 101 the Red River Landing sequence is only hypothetical, the normal curves have not been carried further than that. Also, only on those days of observations at Red River Landing have the values of Vicksburg discharge been plotted on Plate 10, and these have been given the Red River Landing numbers.

Tabulation IX gives the equivalent gauge heights and X the normal curves.

As a final summary of the results of this investigation of the 1884–'85 data, it has confirmed the suggestions of former data as to the existence of a normal curve at each point, and its shifting from time to time on the gauge scale. It has enabled us to determine these normal curves from Helena to Carrollton with a degree of precision believed to be within 0.2 feet in the total range on any of the gauges. It has established the fact that changes of plane, at all but the low stages, are not local phenomena, but are transmitted down the river, simply receiving as additional effects all further changes that may occur below. It has given us absolute values of several changes of plane occurring below Helena, and these confirm former conclusions in regard to the very large value of these changes at the mouth of Red River, when compared with similar changes at other points. And last, it has enabled us to trace out in one instance the complex operation of a law that all admit is true, viz, that having a given variation of volume at the head of the river through a period and given variations of the tributaries below, the discharge at any instant in the period and at any point in its course is absolutely determined.

Very respectfully, your obedient servant,

JAMES A. SEDDON,
Assistant Engineer.

Lieut. Col. CHAS. R. SUTER,
Corps of Engineers, U. S. A.,
St. Louis, Mo

[illegible] *Helena normal curves 1884–'85, with the corresponding Arkansas City normal curves as given by the equivalent gauge relation.*

Point number.	General value of discharge.	Helena gauge for curve (1).	Arkansas City equivalent gauge on lines (1)	Arkansas City equivalent gauge on lines (3)	Helena gauge for curve (2).	Arkansas City equivalent gauge on line (2) = gauge for curve (2).	Helena gauge for curve (3).	Arkansas City equivalent gauge on lines (1)	Arkansas City equivalent gauge on lines (3)	Helena gauge for curve (4).	Arkansas City equivalent gauge on line (3) = gauge for curve (5).	Helena gauge for curve (5).	Arkansas City equivalent gauge on line (3) = gauge for curve (7).	Helena gauge for curve (6).	Arkansas City equivalent gauge on line (3) = gauge for curve (8).
			Equals Arkansas City gauge for curves (1)	Equals Arkansas City gauge for curves (6)				Equals Arkansas City gauge for curves (3)	Equals Arkansas City gauge for curves (4)						
1	135	5.17	4.43	6.08	4.47	2.57	6.67	5.85	7.45	7.77	8.49	6.27	7.07	7.37	8.11
2	170	7.53	6.65	8.25	6.83	4.79	9.03	8.07	9.67	10.13	10.71	8.63	9.29	9.73	10.33
3	209	9.88	8.88	10.48	9.18	7.02	11.38	10.29	11.89	12.48	12.93	10.98	11.52	12.08	12.56
4	251	12.24	11.10	12.70	11.54	9.24	13.74	12.52	14.12	14.84	15.16	13.34	13.74	14.44	14.78
5	297	14.59	13.32	14.92	13.89	11.46	16.09	14.74	16.34	17.19	17.38	15.69	15.96	16.79	17.00
6	346	16.94	15.55	17.15	16.24	13.69	18.44	16.96	18.56	19.54	19.60	18.04	18.19	19.14	19.22
7	398	19.30	17.77	19.37	18.60	15.91	20.80	19.19	20.79	21.90	21.83	20.40	20.41	21.50	21.45
8	454	21.65	19.99	21.59	20.95	18.13	23.15	21.41	23.01	24.25	24.05	22.75	22.63	23.85	23.67
9	514	24.01	22.22	23.82	23.31	20.36	25.51	23.63	25.23	26.61	26.27	25.11	24.85	26.21	25.89
10	579	26.36	24.44	26.04	25.66	22.58	27.86	25.86	27.46	28.96	28.49	27.46	27.08	28.56	28.12
11	647	28.71	26.66	28.26	28.01	24.80	30.21	28.08	29.68	31.31	30.72	29.81	29.30	30.91	30.34
12	720	31.07	28.89	30.49	30.37	27.02	32.57	30.30	31.90	33.67	32.94	32.17	31.52	33.27	32.56
13	796	33.42	31.11	32.71	32.72	29.25	34.92	32.53	34.13	36.02	35.16	34.52	33.75	35.63	34.79
14	878	35.78	33.33	34.93	35.08	31.47	37.28	34.75	36.35	38.38	37.39	36.88	35.97	37.98	37.01
15	964	38.13	35.55	37.15	....	....	39.63	36.97	38.57	40.73	39.61	39.23	38.19	40.33	39.23
16	1,055	40.48	37.78	39.38	....	....	41.98	39.19	40.79	43.08	41.83	41.58	40.42	42.68	41.56
17	1,151	42.84	40.00	41.60	....	....	44.34	41.42	43.02	45.44	44.06	43.94	42.64	45.04	43.68
18	1,252	45.19	42.22	43.82	....	....	46.69	43.64	45.24	47.79	46.28	46.29	44.86	47.39	45.90
19	1,358	47.55	44.45	46.05	....	....	49.05	45.86	47.46	50.15	48.50	48.65	47.09	49.75	48.12

TABULATION II.—*Helena-Arkansas City equivalent gauge heights.*

Arkansas City dates.	Arkansas City gauge.	Arkansas City discharge.	Number of observation.	Helena plane.	Helena equivalent gauge.
1884.					
Oct. 13	20.15	455 t	1	Curve 1	21.65
14	19.50	447	2	...do	21.35
15	18.85	423	3	...do	20.40
16	18.40	406	4	...do	19.85
17	18.15	405 t	5	...do	19.60
18	18.10	414	6	...do	20.00
19	18.25	409 t	......	...do	19.80
20	18.45	405	7	...do	19.60
21	18.50	419	8	...do	20.15
22	18.40	414	9	...do	20.00
23	18.20	417	10	...do	20.10
24	17.95	394	11	...do	19.10
25	17.55	390 t	12	...do	18.90
26	17.10	380 t	......	......	......
27	16.75	375	13	Curve 2	17.55
28	16.45	357	14	...do	16.75
29	16.20	354	15	...do	16.65
30	16.05	352	16	...do	16.55
31	16.30	352	17	...do	16.55
Nov. 1	16.50	366	18	...do	17.10
2	16.60	368 t	......	...do	17.20
3	16.40	352	19	...do	16.60
4	16.25	358	20	...do	16.80
5	16.10	362	21	...do	17.00
6	16.00	359	22	...do	16.95
7	15.70	345	23	...do	16.20
8	15.20	338	24	...do	15.85
9	14.65	323 t	......	...do	15.25
10	14.00	313	25	...do	14.75
11	13.35	299	26	...do	14.00
12	12.75	296	27	...do	13.80
13	12.25	285	28	...do	13.35
14	11.70	269	29	...do	12.40
15	11.20	268	30	...do	12.40
16	10.70	260 t	......	...do	12.00
17	10.25	254	31	...do	11.70
18	9.85	256 t	......	...do	11.80
19	9.50	255 t	......	...do	11.75
20	9.25	241	34	...do	11.00
21	9.05	250	35	...do	11.45
22	8.95	253	36	...do	11.65
23	9.00	250 t	......	...do	11.45
24	8.90	250 t	......	...do	11.45
25	8.85	243	38	...do	11.10
26	8.65	246	39	...do	11.20
27	8.60	238	40	...do	10.80
28	8.50	240 t	......	...do	10.90
29	8.65	241	41	...do	10.95
30	9.10	250 t	......	...do	11.45
Dec. 1	9.75	259	42	...do	11.90
2	10.65	283	43	...do	13.20
3	11.40	288	44	...do	13.40
4	11.90	292	45	...do	13.70
5	12.00	287	46	...do	13.40
6	11.60	285 t	......	...do	13.30
7	10.85	270 t	......	...do	12.50
8	10.30	260	48	...do	12.00
9	9.55	252	49	...do	11.60
10	8.80	247	50	...do	11.30
11	8.20	238 t	......	...do	10.80
12	7.80	234	52	......	......
13	7.40	221	53	Curve 1	10.70
14	7.50	220 t	......	...do	10.60
15	8.85	243	54	...do	11.85
16	10.95	286	55	...do	14.05
17	12.75	321	56	...do	15.90
18	15.00	......	......	...do	......
19	16.55	365	58	...do	17.85
20	17.60	390	59	...do	18.90
21	18.10	404 t	......	...do	19.60
22	18.40	415	60	...do	20.05
23	18.40	410 t	......	...do	19.80
24	18.15	396	62	...do	19.20
25	17.85	395 t	......	...do	19.15
26	16.80	365	63	...do	17.85
27	15.85	350 t	......	...do	17.15
1884.					
Dec. 28	15.35	340 t	......	Curve 1	16.65
29	15.00	340	64	...do	16.65
30	16.85	376	65	...do	18.20
31	20.30	458	66	...do	21.75
1885.					
Jan. 1	23.35	657	67	...do	25.60
2	26.15	637	68	...do	28.35
3	28.70	719	69	...do	31.00
4	31.10	......	......	...do	......
5	32.90	......	......	...do	......
6	34.55	......	......	......	......
7	35.55	892	70	Curve 3	37.65
8	36.30	935 t	......	...do	38.85
9	36.85	969	71	...do	39.75
10	37.30	980	72	...do	40.05
11	37.60	991 t	......	...do	40.35
12	38.10	1,016	73	...do	40.95
13	38.50	1,022 t	......	...do	41.20
14	39.05	1,045	75	...do	41.70
15	39.80	1.080 t	......	...do	42.60
16	40.30	1,117	76	...do	43.55
17	40.61	......	......	......	......
18	40.95	......	......	Curve 4	......
19	41.05	......	......	...do	......
20	41.20	1,069	79	...do	43.40
21	41.30	1,069 t	......	...do	43.40
22	41.35	1,072	80	......	......
23	41.50	1,092	81	Curve 3	42.90
24	41.50	......	......	...do	......
25	41.50	......	......	...do	......
26	41.50	......	......	...do	......
27	41.60	......	......	...do	......
28	41.70	......	......	...do	......
29	41.70	......	......	...do	......
30	41.70	......	......	...do	......
31	41.75	1,064	82	...do	42.25
Feb. 1	41.70	1,080 t	......	...do	42.60
2	41.60	1,076	83	......	......
3	41.35	1,049	84	......	......
4	40.80	1,026	85	Curve 4	42.30
5	39.90	980	86	...do	41.10
6	38.70	930	87	...do	39.80
7	37.45	880	......	...do	38.45
8	36.30	838 t	......	...do	37.25
9	35.15	787	89	...do	35.75
10	34.15	760 t	......	......	......
11	33.60	743	90	Curve 3	33.30
12	33.20	730	91	...do	32.90
13	32.95	740 t	......	...do	33.20
14	32.70	745 t	......	...do	33.35
15	32.55	740 t	......	...do	33.20
16	32.25	734	94	...do	33.05
17	32.20	730 t	95	...do	32.90
18	32.25	735	96	...do	33.05
19	32.30	735 t	......	...do	33.05
20	32.20	730 t	......	...do	32.90
21	31.95	726	98	...do	32.75
22	31.35	700 t	......	...do	32.00
23	30.50	669	99	...do	30.95
24	29.65	626	100	...do	29.50
25	28.45	610 t	......	...do	29.00
26	27.05	565 t	......	...do	27.35
27	25.40	510	101	...do	25.55
28	24.00	484	102	...do	24.30
Mar. 1	22.80	......	......	......	......
2	22.10	470	103	......	......
3	21.80	458	104	Curve 1	21.80
4	21.75	460 t	105	...do	21.85
5	21.85	459	106	...do	21.85
6	22.15	471	107	...do	22.30
7	22.60	491	108	...do	23.10
8	23.15	495 t	......	...do	23.25
9	23.85	504	109	...do	23.65
10	24.55	534	110	...do	24.75
11	25.50	560 t	......	...do	25.70
12	26.70	590 t	112	...do	26.75

TABULATION II.—*Helena-Arkansas City equivalent gauge heights*—Continued.

Arkansas City dates.	Arkansas City gauge.	Arkansas City discharge.	Number of observation.	Helena plane.	Helena equivalent gauge.	Arkansas City dates.	Arkansas City gauge.	Arkansas City discharge.	Number of observation.	Helena plane.	Helena equivalent gauge.
1885.						1885.					
Mar. 13	28.10	620 t	......	....	......	Mar. 30	33.30	743	127	Curve 6...	34.00
14	29.25	640 t	114	Curve 5...	29.55	31	32.60	714	128	...do	33.10
15	30.20	675 t	......	...do	30.70	Apr. 1	31.75	687	129	...do	32.20
16	30.85	698	115	...do	31.45	2	30.80	669	130	...do	31.60
17	31.35	717	116	...do	32.05	3	29.90	654	131	....	......
18	32.00	742	117	...do	32.85	4	28.85	618	132	Curve 3...	29.20
19	32.70	767	118	...do	33.60	5	28.00	595 t	......	...do	28.40
20	33.40	779	119	...do	33.95	6	27.35	562	133	...do	27.35
21	34.00	795 t	120	...do	34.45	7	26.90	561	134	...do	27.35
22	34.40	805 t	......	...do	34.80	8	26.75	559	135	...do	27.10
23	34.75	....	......	....	......	9	27.05	567	136	...do	27.40
24	34.85	801	122	....	......	10	27.95	594	......	...do	28.40
25	34.85	791	123	Curve 6...	35.45	11	29.05	628	......	...do	29.55
26	34.75	801	124	...do	35.80	12	30.25	665	......	...do	30.80
27	34.55	789	125	...do	35.35	13	31.00	690	......	...do	31.60
28	34.30	780	......	...do	35.10	14	31.85	....	......	...do	......
29	33.90	765 t	......	...do	34.65	15	32.55	....	......	...do	......

TABULATION III.—*Helena and Arkansas City sequences of discharge with increments between the points, and with sum of the Arkansas and White River discharges.*

Helena dates.	Helena gauge.	Helena plane.	Helena discharge.	Arkansas City gauge.	Arkansas City plane.	Arkansas City discharge.	Increment to discharge between Helena and Arkansas City.	Sum of the Arkansas and White River discharges.
1884.								
Oct. 8	20.25	Curve (1) .	421	20.4	Curve (1) .	465	44	74
9	19.95	...do	412	20.9	...do	480	68	91
10	19.55	...do	403	20.8	...do	477	74	85
11	19.00	...do	392	20.3	...do	463	71	72
12	18.50	...do	380	19.7	...do	447	67	59
13	18.00	...do	369	19.0	...do	430	61	48
14	17.65	...do	361	18.5	...do	417	56	40
15	17.50	...do	358	18.1	...do	407	49	37
16	17.65	...do	361	18.0	...do	404	43	38
17	18.00	...do	369	18.2	...do	410	41	36
18	18.30	...do	376	18.3	...do	412	36	32
19	18.40	...do	379	18.3	...do	412	33	30
20	18.45	...do	380	18.3	...do	412	32	28
21	18.35	...do	378	18.1	...do	407	29	27
22	18.20	...do	372	17.9	...do	402	30	27
23	17.75	...do	364	17.6	...do	394	30	27
24	17.30	....	361 t	17.2	...do	385	24	26
25	16.90	Curve (2) .	360	16.8	...do	376	16	26
26	16.55	...do	352	16.4	...do	366	14	26
27	16.30	...do	347	16.1	...do	359	12	26
28	16.00	...do	340	16.0	...do	357	17	29
29	16.10	...do	343	16.2	...do	361	18	47
30	16.25	...do	346	16.5	...do	368	22	48
31	16.35	...do	349	16.6	...do	370	21	41
Nov. 1	16.50	...do	351	16.5	...do	368	17	36
2	16.15	...do	343	16.3	...do	363	20	37
3	16.00	...do	340	16.2	...do	361	21	45
4	15.80	...do	336	16.0	...do	357	21	47
5	15.55	...do	330	15.8	...do	351	21	41
6	15.15	...do	322	15.4	...do	342	20	37
7	14.75	...do	313	14.8	...do	328	15	34
8	14.20	...do	303	14.1	...do	313	10	31
9	13.60	...do	291	13.6	....	307	16	30
10	13.10	...do	282	13.0	....	298	16	29

TABULATION III.—*Helena and Arkansas City sequences of discharge, etc.*—Continued.

Helena dates.	Helena guage.	Helena plane.	Helena discharge.	Arkansas City gauge.	Arkansas City plane.	Arkansas City discharge.	Increment to discharge between Helena and Arkansas City.	Sum of the Arkansas and White River discharges.
1884.								
Nov. 11	12.65	Curve (2)	274	12.3		289	15	27
12	12.10	...do	263	11.8		280	17	26
13	11.70	...do	254	11.3		270	16	25
14	11.25	...do	247	10.8		263	16	25
15	10.95	...do	240	10.4		260	20	25
16	10.60	...do	234	10.0		256	22	24
17	10.25	...do	228	9.6		255	27	23
18	10.00	...do	223	9.3	Curve (2)	252	29	23
19	9.85	...do	220	9.2	...do	250	30	23
20	9.70	...do	218	9.0	...do	247	29	23
21	9.60	...do	217	9.0	...do	247	30	23
22	9.55	...do	215	9.0	...do	247	32	23
23	9.55	...do	215	8.8	...do	242	27	24
24	9.40	...do	212	8.7	...do	241	29	26
25	9.35	...do	211	8.6	...do	239	28	30
26	9.10	...do	207	8.5	...do	237	30	34
27	8.90	...do	204	8.6	...do	239	35	41
28	8.90	...do	204	9.0	...do	247	43	48
29	9.10	...do	207	9.5	...do	252	45	53
30	9.75	...do	219	10.3	...do	272	53	55
Dec. 1	10.50	...do	232	11.0	...do	287	55	54
2	10.85	...do	239	11.7	...do	301	62	63
3	10.95	...do	241	11.9	...do	305	64	55
4	10.85	...do	239	11.7	...do	301	62	48
5	10.65	...do	235	11.0	...do	287	52	43
6	10.25	...do	228	10.4	...do	273	45	39
7	9.70	...do	218	9.7	...do	260	42	37
8	8.95	...do	205	9.0	...do	247	42	36
9	8.35	...do	195	8.4	...do	234	39	38
10	7.85		180	8.0	...do	227	47	39
11	7.45	Curve 1	170	7.6	...do	220	50	39
12	7.25	...do	167	7.5	...do	218	51	40
13	7.20	...do	166	8.8	...do	242	76	60
14	7.75	...do	173	10.5	...do	276	103	105
15	8.70	...do	189	12.6		312	123	119
16	9.85	...do	207	14.5		335	128	141
17	11.00	...do	229	16.1	Curve 1	358	129	155
18	12.10	...do	248	17.2	...do	385	137	156
19	13.25	...do	270	18.0	...do	403	133	143
20	14.20	...do	289	18.3	...do	412	123	123
21	14.85	...do	301	18.4	...do	413	112	110
22	15.25	...do	310	18.3	...do	412	102	102
23	15.25	...do	310	17.9	...do	402	92	90
24	14.80	...do	300	17.2	...do	385	85	78
25	13.95	...do	283	16.1	...do	358	75	73
26	13.00	...do	266	15.4	...do	341	75	67
27	12.10	...do	248	15.8	...do	350	102	64
28	12.15	...do	249	16.4	...do	366	117	60
29	12.90	...do	263	19.1	...do	432	169	80
30	14.85	...do	301	22.6	...do	526	225	166
31	17.75	...do	363	25.5	...do	610	247	245
1885.								
Jan. 1	20.75	...do	433	28.0	...do	690	257	271
2	23.90	...do	512	30.5	...do	777	265	304
3	26.90	...do	594	32.4	...do	843	249	303
4	29.15		634	34.1		870	236	305
5	30.60	Curve 3	659	35.3	Curve 3	899	240	291
6	31.55	...do	688	36.1	...do	930	242	268
7	31.95	...do	700	36.7	...do	954	254	247
8	32.25	...do	710	37.2	...do	973	263	229
9	32.50	...do	717	37.5	...do	985	268	213
10	32.80	...do	727	37.9	...do	1,001	274	197
11	33.10	...do	737	38.3	...do	1,017	280	188
12	33.70	...do	756	38.8	...do	1,039	283	184
13	34.35	...do	779	39.6	...do	1,072	293	179
14	35.00	...do	800	40.2	...do	1,099	299	178
15	35.80		805	40.5		1,107	302	165
16	36.45	Curve 4	810	40.9		1,119	309	162
17	36.90	...do	825	41.0		1,114	289	161

TABULATION III.—*Helena and Arkansas City sequences of discharge, etc.*—Continued.

Helena dates.	Helena guage.	Helena plane.	Helena discharge.	Arkansas City guage.	Arkansas City plane.	Arkansas City discharge.	Increment to discharge between Helena and Arkansas City.	Sum of the Arkansas and White River discharges.
1885.								
Jan. 18	37.25	Curve (4)	838	41.2		1,108	270	162
19	37.60		860	41.3		1,103	243	178
20	38.00		890	41.3		1,090	200	164
21	38.30	Curve 3	915	41.4	Curve 4	1,082	167	152
22	38.70	...do	929	41.5	...do	1,087	158	139
23	39.15	...do	947	41.5	...do	1,087	140	125
24	39.50	...do	959	41.5	...do	1,087	128	117
25	39.89	...do	970	41.6	...do	1,091	121	110
26	40.10	...do	983	41.7	...do	1,095	112	104
27	40.35	...do	992	41.7	...do	1,095	103	99
28	40.45	...do	996	41.7	...do	1,095	99	100
29	40.60	...do	1,002	41.7	...do	1,095	93	97
30	40.60	...do	1,002	41.7	...do	1,095	93	98
31	40.50		996	41.7		1,082	86	95
Feb. 1	39.75		945	41.4		1,055	110	96
2	38.50	Curve (4)	883	41.0	Curve (5)	1,022	139	94
3	36.85	...do	823	40.0	...do	981	158	93
4	34.85	...do	757	39.0	...do	940	183	92
5	32.75	...do	691	37.8	...do	894	203	91
6	30.95	...do	635	36.6	...do	849	214	96
7	29.30	...do	588	35.4	...do	804	216	106
8	27.90		568	34.4	...do	770	202	129
9	27.00	Curve (3)	555	33.8	...do	749	194	147
10	26.60	...do	545	33.3	...do	732	187	153
11	26.55	...do	543	33.0		738	195	160
12	26.65	...do	546	32.8		745	199	158
13	26.90	...do	553	32.6	Curve (4)	743	190	152
14	27.00	...do	555	32.4	...do	738	183	139
15	27.35	...do	565	32.2	...do	730	165	124
16	28.00	...do	583	32.2	...do	730	147	110
17	28.65	...do	602	32.3	...do	734	132	98
18	29.35	...do	621	32.2	...do	730	109	89
19	29.50	...do	625	32.0	...do	724	99	84
20	29.35	...do	621	31.5	...do	706	85	80
21	28.60	...do	600	30.8	...do	683	83	74
22	27.45	...do	569	30.0	...do	657	88	70
23	26.05	...do	530	28.9	...do	622	92	67
24	24.50	...do	489	27.4	...do	577	88	64
25	22.70	...do	443	26.1	...do	540	97	62
26	21.20	...do	407	24.5	...do	494	87	63
27	19.45		384	23.2		474	90	67
28	18.35		370	22.3		463	93	80
Mar. 1	17.45	Curve (1)	357	21.9	Curve (6)	463	106	106
2	16.80	...do	343	21.8	...do	460	117	128
3	16.50	...do	336	21.8	...do	460	124	135
4	16.50	...do	336	22.0	...do	466	130	140
5	16.85	...do	343	22.5	...do	480	137	146
6	17.50	...do	358	23.0	...do	493	135	144
7	18.40	...do	379	23.7	...do	512	133	141
8	19.30	...do	399	24.5	...do	535	136	136
9	20.50	...do	427	25.2	...do	554	127	132
10	22.00	...do	463	26.4	...do	590	127	121
11	23.80		500	27.7		616	116	109
12	25.80	Curve (5)	533	28.9	Curve (7)	634	101	101
13	27.60	...do	583	29.9	...do	666	83	93
14	28.75	...do	615	30.6	...do	690	75	87
15	29.45	...do	637	31.2	...do	709	72	84
16	30.00	...do	652	31.8	...do	729	77	92
17	30.80	...do	677	32.5	...do	753	76	103
18	31.65		695	33.3		770	75	107
19	32.40		714	34.0		789	75	102
20	33.10		728	34.3		790	62	106
21	33.55		732	34.6		792	60	106
22	33.70	Curve (6)	735	34.8	Curve (8)	795	60	98
23	33.55	...do	729	35.0	...do	803	74	88
24	33.45	...do	725	34.9	...do	800	75	86
25	33.25	...do	720	34.7	...do	793	73	83
26	32.90	...do	708	34.3	...do	779	71	82

TABULATION III.—*Helena and Arkansas City sequences of discharge, etc.*—Continued.

Helena dates.	Helena gauge.	Helena plane.	Helena discharge.	Arkansas City gauge.	Arkansas City plane.	Arkansas City discharge.	Increment to discharge between Helena and Arkansas City.	Sum of the Arkansas and White River discharges.
1885.								
Mar. 27	32.40	Curve (6)	693	34.0	Curve (8)	769	76	82
28	31.65	...do	670	33.4	...do	748	78	86
29	30.70	...do	641	32.8	...do	727	86	87
30	29.55	...do	607	32.1	...do	704	97	87
31	28.30	...do	572	31.1	...do	671	99	87
April 1	26.90		545	30.0		647	102	85
2	25.60	Curve 3	517	29.2	Curve 4	631	114	83
3	24.65	...do	493	28.2	...do	600	107	81
4	23.90	...do	473	27.5	...do	580	107	83
5	23.30	...do	458	27.0	...do	565	107	90
6	23.00	...do	450	26.8	...do	559	109	94
7	23.10	...do	453	27.0	...do	565	112	95
8	23.60	...do	465	27.7	...do	586	121	118
9	24.70	...do	494	28.8	...do	619	125	135
10	26.20	...do	535	30.0	...do	657	122	135

TABULATION IV.—*Arkansas City-Red River Landing equivalent gauge heights.*

Red River Landing dates.	Red River Landing gauge.	Red River Landing discharge.	Number of observation.	Arkansas City plane.	Arkansas City equivalent gauge.	Red River Landing dates.	Red River Landing gauge.	Red River Landing discharge.	Number of observations.	Arkansas City plane.	Arkansas City equivalent gauge.
1884.						1884.					
Oct. 11	14.5			Curve (1)		Nov. 8	13.4	333	25	Curve (1)	15.0
12	15.3			...do		9	13.3	328 t		...do	14.8
13	15 9			...do		10	13.2	323	26	...do	14.5
14	16.4			...do		11	12.9	317	27	...do	14.3
15	16.5	395	8	...do	17.6	12	12.6	320	28	...do	14.4
16	16.4	402	9	...do	17.9	13	12.2	303	29	...do	13.7
17	16.1	388	10	...do	17.3	14	11.9	301	30	...do	13 5
18	15.7	374	11	...do	16.8	15	11.5				
19	15.5	371 t		...do	16.6	16	11.0				
20	15.3	367	12	...do	16.5	17	10.6				
21	15.2	377	13	...do	16.9	18	10.1				
22	15.2	368	14	...do	16.5	19	9.7				
23	15.2	367 t		...do	16.4	20	9.3				
24	15.2	366	15	...do	16.4	21	8.9				
25	15.3	369	16	...do	16.5	22	8.6				
26	15.3			...do		23	8.6				
27	15.2			...do		24	8.3	247	37	Curve (2)	9.0
28	15.0	365	17	...do	16.4	25	8.1	239	38	...do	8.6
29	14.7	358 t		...do	16.1	26	8.0	230	39	...do	8.2
30	14.4	348	18	...do	15.7	27	7.9	228 t		...do	8.0
31	14.1	353	19	...do	15.9	28	7.9	225	40	...do	7.9
Nov. 1	13.8	359	20	Curve (1)	16.1	29	7.7	229	41	...do	8.1
2	13.7			...do		30	7.6			...do	
3	13.6			...do							
4	13.6	553	21	...do	15.9	Dec. 1	7.5	237	42	Curve (2)	8.5
5	13.7	843	22	...do	15.5	2	7.5	235	43	...do	8.4
6	13.7	344	23	...do	15.5	3	7.7	232	44	...do	8.3
7	13.6	335	24	...do	15.1	4	8.1	254	45	...do	9.5

TABULATION IV.—*Arkansas City-Red River Landing equivalent gauge heights*—Continued.

Red River Landing dates.	Red River Landing gauge.	Red River Landing discharge.	Number of observation.	Arkansas City plane.	Arkansas City equivalent gauge.
1884.					
Dec. 5	8.8			Curve (2)	
6	9.5	257	46	...do	9.6
7	9.8			...do	
8	10.0	264	47	...do	10.0
9	10.0	259	48	...do	9.7
10	9.8	262	49	...do	9.9
11	9.5			...do	
12	9.2	256	50	...do	9.5
13	8.7	239	51	...do	8.6
14	8.5			...do	
15	8.4			...do	
16	7.9	234	52	...do	8.4
17	7.7			...do	
18	8.0			...do	
19	9.0	251	53	...do	9.2
20	10.3	291	54	...do	11.2
21	11.9			...do	
22	13.4	332	55		
23	14.5	365 t	56	Curve (1)	16.4
24	15.2	385 t	57	...do	17.2
25	15.8	402 t		...do	17.9
26	16.1	412 t		...do	18.3
27	16.2	415 t		...do	18.4
28	16.3	420 t		...do	18.6
29	17.0			...do	
30	18.2	421	59	...do	18.7
31	19.4	449	60	...do	19.8
1885.					
Jan. 1	20.4			Curve (1)	
2	21.3	484	61	...do	21.1
3	23.2	522	62	...do	22.5
4	25.4			...do	
5	27.7			...do	
6	29.7	*685		...do	27.8
7	31.5	*758		...do	30.0
8	32.8	826	63	...do	31.9
9	34.1	870 t	64	...do	33.1
10	35.2	896	65	...do	
11	35.9			Curve (3)	
12	36.6	935 t		...do	36.2
13	37.2	971	66	...do	37.1
14	37.6	982 t		...do	37.4
15	38.0	1,002 t		...do	37.9
16	38.5	1,027 t		...do	38.5
17	38.9	1,048	67	...do	39.0
18	39.2	1,062 t		...do	39.4
19	39.4	1,073	68	...do	39.6
20	39.8	1,094 t		...do	40.1
21	40.1	1,101	69		40.3
22	40.4				
23	40.7				
24	41.0				
25	41.2				
26	41.4				
27	41.5			Curve (4)	
28	41.6			...do	
29	41.7	1,127	73	...do	42.5
30	41.8	1,130 t	74	...do	42.5
31	41.8			...do	

Red River Landing dates.	Red River Landing gauge.	Red River Landing discharge	Number of observation.	Arkansas City plane.	Arkansas City equivalent gauge.
1885.					
Feb. 1	41.9	1,135 t		Curve (4)	42.7
2	41.9	1,133	75	...do	42.6
3	41.9			...do	
4	41.9	1,135 t	76	...do	42.7
5	42.0	1,140 t	77	...do	42.8
6	41.9	1,137	78		
7	41.8	1,130	79		
8	41.7	1,115 t		Curve (5)	43.2
9	41.4	1,085 t		...do	42.4
10	41.1	1,060 t	80	...do	41.9
11	40.8	1,043	81	...do	41.5
12	40.5	1,020 t	82	...do	41.0
13	40.1	1,000 t		...do	40.5
14	39.7	979	83	...do	40.0
15	39.2	955 t		...do	39.4
16	38.8	943	84	...do	39.1
17	38.4	918 t	85		
18	38.0	900 t			
19	37.7	886	86	Curve (4)	36.5
20	37.5	884	87	...do	36.5
21	37.3	871	88	...do	36.2
22	37.1			...do	
23	36.9			...do	
24	36.8	870	89	...do	36.1
25	36.8	863	90	...do	36.0
26	36.4	845 t		...do	35.5
27	35.9	815	91	...do	34.7
28	35.3	793	92	...do	34.0
Mar. 1	34.6	768 t		Curve (4)	33.3
2	33.9	728	93	...do	32.1
3	33.2	705	94	...do	31.5
4	32.2	670 t		...do	30.4
5	31.3	663	95		
6	30.5	638	96		
7	29.8	625 t	97	Curve (6)	27.6
8	29.3			...do	
9	28.9	617	98	...do	27.3
10	28.6			...do	
11	28.5	624	99	...do	27.6
12	28.6			...do	
13	28.7	621	100	...do	27.4
14	29.1	623	101	...do	27.5
15	29.6				
16	30.2				
17	30.8				
18	31.4				
19	32.0				
20	32.4				
21	33.0				
22	33.6				
23	34.1				
24	34.3				
25	34.6				
26	35.0				
27	35.1				
28	35.2				
29	35.3				
30	35.3				

*These were scaled from comparison of Carrollton and Red River Landing sequence.

TABULATION V.—*Arkansas City normal curves, with the corresponding Red River Landing equivalent gauge heights, on the various lines of the equivalent gauge relation, giving the various Red River Landing normal curves.*

Arkansas City gauge.	Red River Landing equivalent gauge on lines.					Values of discharge scaled on the various Arkansas City normal curves.							
	a.	1	2	3	4	1	2	3	4	5	6	7	8
4	4.85	4.25	10.05	10.45	9.55	128	158	......	......	......	......	......	......
6	6.50	5.90	11.70	12.10	11.20	160	191	......	......	......	......	......	......
8	8.15	7.55	13.35	13.75	12.85	193	227	......	......	......	......	......	......
10	9.80	9.20	15.00	15.40	14.50	229	260	......	......	......	......	......	......
12	11.45	10.85	16.65	17.05	16.15	269	307	......	......	......	......	......	......
14	13.10	12.50	18.30	18.70	17.80	310	352	......	......	......	......	......	......
16	14.75	14.15	19.95	20.35	19.45	356	400	......	......	......	......	......	......
18	16.39	15.79	21.59	21.99	21.09	404	451	......	......	......	......	......	......
20	18.04	17.44	23.24	23.64	22.74	454	505	......	......	......	......	......	......
22	19.69	19.09	24.89	25.29	24.39	509	......	......	429	402	......	......	......
24	21.34	20.74	26.54	26.94	26.04	566	......	527	481	453	521	......	......
26	......	22.39	28.19	28.59	27.69	626	......	583	536	507	578	547	......
28	......	24.04	29.84	30.24	29.34	691	......	645	595	563	639	605	573
30	......	25.68	31.48	31.88	30.98	759	......	710	657	624	703	670	635
32	......	27.33	33.13	33.53	32.63	829	......	779	724	689	772	736	701
34	......	28.98	34.78	35.18	34.28	903	......	850	792	756	843	805	769
36	......	30.63	36.43	36.83	35.93	983	......	926	865	827	919	879	840
38	......	32.28	38.08	38.48	37.58	1,066	......	1,005	942	902	998	957	916
40	......	33.93	39.73	40.13	39.23	1,150	......	1,090	1 023	981	......	1,041	996
42	......	35.57	41.37	41.77	40.87	1,241	......	1,178	1,107	1,063	......	......	......
44	......	37.22	43.02	43.42	42.32	1,336	......	1,270	1,196	1,149	......	......	......
46	......	38.87	44.67	45.07	43.97	1,435	......	1,365	1,288	1,238	......	......	......
48	......	40.52	......	......	......	1,539	......	......	......	......	......	......	......

TABULATION VI.—*Arkansas City and Red River Landing sequences of discharge, with increments between the points.*

Red River Landing dates.	Red River Landing gauge.	Red River Landing plane.	Red River Landing discharge.	Arkansas City discharge.	Increment to discharge between Arkansas City and Red River Landing.	Red River Landing date.	Red River Landing gauge.	Red River Landing plane.	Red River Landing discharge.	Arkansas City discharge.	Increment to discharge between Arkansas City and Red River Landing.
1884.						1884.					
Oct. 11	14.5	....	......	......	......	Nov. 9	13.3	Curve (1)	332	361	—29
12	15.3	....	......	......	......	10	13.2	...do	330	357	27
13	15.9	....	......	......	......	11	12.9	...do	321	351	30
14	16.4	....	......	......	......	12	12.6	...do	313	342	29
15	16.5	Curve (*a*)	406	480	—74	13	12.2	...do	303	328	25
16	16.4	...do	403	477	74	14	11.9	...do	296	313	17
17	16.1	...do	395	463	68	15	11.5	....	291	307	16
18	15.7	...do	383	447	64	16	11.0	....	286	298	12
19	15.5	...do	377	430	53	17	10.6	....	281	289	8
20	15.3	...do	370	417	47	18	10.1	....	276	280	— 4
21	15.2	...do	368	407	39	19	9.7	....	271	270	+ 1
22	15.2	...do	368	404	36	20	9.3	Curve (2)	268	263	+ 5
23	15.2	...do	368	410	42	21	8.9	...do	258	260	— 2
24	15.2	...do	368	412	44	22	8.6	...do	251	256	5
25	15.3	...do	370	412	42	23	8.6	...do	251	255	4
26	15.3	...do	370	412	42	24	8.3	...do	245	252	7
27	15.2	...do	368	407	39	25	8.1	...do	240	250	10
28	15.0	...do	362	402	40	26	8.0	...do	237	247	10
29	14.7	....	360	394	34	27	7.9	...do	235	247	12
30	14.4	....	359	385	26	28	7.9	...do	235	247	12
31	14.1	Curve (1)	355	376	21	29	7.7	...do	231	242	11
Nov. 1	13.8	...do	346	366	20	30	7.6	...do	229	241	12
2	13.7	...do	343	359	16	Dec. 1	7.5	...do	226	239	13
3	13.6	...do	340	357	17	2	7.5	...do	226	237	11
4	13.6	...do	340	361	21	3	7.7	...do	231	239	8
5	13.7	...do	343	368	25	4	8.1	...do	240	247	— 7
6	13.7	...do	343	370	27	5	8.8	...do	257	252	+ 5
7	13.6	...do	340	368	28	6	9.5	...do	273	272	+ 1
8	13.4	...do	335	363	—28	7	9.8	...do	280	287	— 7

TABULATION VI.—*Arkansas City and Red River Landing sequences of discharge, with increments between the points*—Continued.

Red River Landing dates.	Red River Landing gauge.	Red River Landing plane.	Red River Landing discharge.	Arkansas City discharge.	Increment to discharge between Arkansas City and Red River Landing.	Red River Landing date.	Red River Landing gauge.	Red River Landing plane.	Red River Landing discharge.	Arkansas City discharge.	Increment to discharge between Arkansas City and Red River Landing.
1884.						1885.					
Dec. 8	10.0	Curve (2)	286	301	−15	Feb. 2	41.9	Curve (5)	1,135	1,095	+40
9	10.0	...do	286	305	19	3	41.9	...do	1,135	1,095	40
10	9.8	...do	280	301	21	4	41.9	...do	1,135	1,095	40
11	9.5	...do	273	287	14	5	42.0	...do	1,141	1,095	46
12	9.2	...do	267	273	6	6	41.9	...do	1,135	1,082	53
13	8.7	...do	253	260	− 7	7	41.8	...do	1,130	1,055	75
14	8.5	...do	250	247	+ 3	8	41.7	....	1,115	1,022	93
15	8.4	...do	247	234	13	9	41.4	....	1,090	981	109
16	7.9	...do	235	227	8	10	41.1	....	1,062	940	122
17	7.7	...do	230	220	10	11	40.8	Curve (6)	1,036	894	142
18	8.0	...do	237	218	19	12	40.5	...do	1,020	849	171
19	9.0	...do	260	242	18	13	40.1	...do	1,000	804	196
20	10.3	...do	293	276	17	14	39.7	...do	981	770	211
21	11.9	....	330	312	18	15	39.2	...do	957	749	208
22	13.4	....	348	335	13	16	38.8	...do	937	732	205
23	14.5	Curve (1)	366	358	8	17	38.4	...do	918	738	180
24	15.2	...do	386	385	1	18	38.0	...do	899	745	154
25	15.8	...do	403	403	0	19	37.7	...do	885	743	142
26	16.1	...do	413	412	1	20	37.5	...do	875	738	137
27	16.2	...do	416	413	3	21	37.3	...do	866	730	136
28	16.3	...do	419	412	7	22	37.1	....	867	730	137
29	17.0	....	424	402	22	23	36.9	Curve (7)	867	734	133
30	18.2	....	435	385	50	24	36.8	...do	863	730	133
31	19.4	....	449	358	+91	25	36.8	...do	863	724	139
1885.						26	36.4	...do	846	706	140
Jan. 1	20.4	....	468	341	+127	27	35.9	...do	824	683	141
2	21.3	....	485	350	135	28	35.3	...do	798	657	141
3	23.2	....	522	366	156	Mar. 1	34.6	...do	768	622	146
4	25.4	....	560	432	128	2	33.9	...do	738	577	161
5	27.7	Curve (3)	605	526	79	3	33.2	...do	708	540	168
6	29.7	...do	684	610	74	4	32.2	...do	669	494	175
7	31.5	...do	748	690	58	5	31.3	....	652	474	178
8	32.8	...do	813	777	36	6	30.5	....	641	463	178
9	34.1	...do	874	843	31	7	29.8	....	632	463	169
10	35.2	....	895	870	25	8	29.3	....	625	460	165
11	35.9	....	915	899	16	9	28.9	Curve (8)	621	460	161
12	36.6	Curve (4)	935	930	5	10	28.6	...do	610	466	144
13	37.2	...do	962	954	8	11	28.5	...do	606	480	126
14	37.6	...do	982	973	9	12	28.6	...do	610	493	117
15	38.0	...do	1,002	985	17	13	28.7	...do	614	512	102
16	38.5	...do	1,027	1,001	26	14	29.1	...do	629	535	94
17	38.9	...do	1,048	1,017	31	15	29.6	...do	649	554	95
18	39.2	...do	1,062	1,039	23	16	30.2	...do	671	590	81
19	39.4	...do	1,072	1,072	± 0	17	30.8	....	681	616	65
20	39.8	...do	1,094	1,099	− 5	18	31.4	Curve (9)	685	634	51
21	40.1	....	1,103	1,107	4	19	32.0	...do	709	666	43
22	40.4	....	1,115	1,119	− 4	20	32.4	...do	725	690	35
23	40.7	....	1,118	1,114	+ 4	21	33.0	...do	750	709	41
24	41.0	....	1,120	1,108	12	22	33.6	...do	775	729	46
25	41.2	....	1,120	1,103	17	23	34.1	....	785	753	32
26	41.4	....	1,120	1,090	30	24	34.3	....	795	770	25
27	41.5	Curve (5)	1,115	1,082	33	25	34.6	....	801	789	12
28	41.6	...do	1,120	1,087	33	26	35.0	....	805	790	15
29	41.7	...do	1,125	1,087	38	27	35.1	....	804	792	12
30	41.8	...do	1,130	1,087	43	28	35.2	Curve (10)	808	795	13
31	41.8	...do	1,130	1,091	39	29	35.3	...do	811	803	8
Feb. 1	41.9	...do	1,135	1,095	+40	30	35.3	...do	811	800	+11

TABULATION VII.—*Red River Landing-Carrollton equivalent gauge heights.*

Carrollton dates.	Carrollton gauge.	Carrollton discharge.	No. of observation.	Red River Landing plane.	Red River Landing equivalent gauge.
1884.					
Oct. 15	3.55	Carrollton discharge assumed same as Red River Landing discharge.			16.4
16	3.60				16.5
17	3.25				16.4
18	3.05				16.1
19	2.90				15.7
20	3.10				15.5
21	3.10				15.3
22	3.15				15.2
23	3.30				15.2
24	3.55				15.2
25	3.30				15.2
26	3.60				15.3
27	3.80				15.3
28	3.50				15.2
29	3.50				15.0
30	3.10				14.7
31	2.85				14.4
Nov. 1	2.60				14.1
2	2.40				13.8
3	2.45				13.7
4	2.40				13.6
5	2.55				13.6
6	2.45				13.7
7	2.55				13.7
8	2.45				13.6
9	2.40				13.4
10	2.20				13.3
11	2.20				13.2
12	2.20				12.9
13	2.05				12.6
14	1.95				12.2
15	1.75				11.9
16	1.30				11.5
17	1.40				11.0
18	1.45				10.6
19	1.25				10.1
20	1.15				9.7
21	1.05				9.3
22	1.50				8.9
23	1.50				8.6
24	1.45				8.6
25	1.20				8.3
26	1.35				8.1
27	1.40				8.0
28	1.40				7.9
29	0.80				7.9
30	0.55				7.7
Dec. 1	0.40				7.6
2	0.35				7.5
3	0.55				7.5
4	0.50				7.7
5	1.15				8.1
6	1.85				8.8
7	1.50				9.5
8	1.35				9.8
9	1.30				10.0
10	1.50				10.0
11	1.40				9.8
12	1.45				9.5
13	1.10				9.2
14	1.10				8.7
15	1.05				8.5
16	0.70				8.4
17	0.65				7.9
18	0.70				7.7
19	0.55				8.0
20	0.50				9.0
21	1.10				10.3

Carrollton dates.	Carrollton gauge.	Carrollton discharge.	No. of observation.	Red River Landing plane.	Red River Landing equivalent gauge.
1884.					
Dec. 22	2.20				
23	2.45	326	55	Curve (1)	13.1
24	2.70	343	56	do	13.7
25	2.90	357	57	do	14.2
26	2.90	387	58	do	15.2
27	3.20			do	
28	3.40			do	
29	3.80	437	59	do	16.9
30	3.85				
31	4.10				
1885.					
Jan. 1	4.50				
2	4.85				
3	5.25				
4	6.85				
5	7.95				
6	8.00				
7	8.45	675 t	63	Curve (3)	29.5
8	9.15	736	64	do	31.0
9	9.85	803	65	do	32.6
10	10.40	827	66	do	33.1
11	11.00				
12	11.20				
13	11.50				
14	11.65	901	68	Curve (4)	35.9
15	11.95	915 t	69	do	36.2
16	12.40	929	70	do	36.5
17				do	
18	12.55			do	
19	12.45			do	
20	12.80	972	72	do	37.4
21	12.95	975	73	do	37.5
22	13.55				
23	13.55				
24	13.15				
25	13.20				
26	13.20				
27	13.30				
28	13.40	1043	76	Curve (5)	40.1
29	13.45	1042	77	do	40.0
30	13.45	1043	78	do	40.1
31	13.55	1045 t	79	do	40.1
Feb. 1	13.45			do	
2	13.55			do	
3	13.60	1047	81	do	40.1
4	13.40			do	
5	13.40			do	
6	13.45			do	
7	13.35	1040	83	do	40.0
8	13.45			do	
9	13.45			do	
10	13.25				
11	13.00				
12	13.15	989	86	Curve (6)	39.8
13	12.95	980	87	do	39.7
14	13.00	956	88	do	39.2
15	12.40			do	
16	12.55	930	89	do	38.6
17	12.30			do	
18	12.30			do	
19	12.25			do	
20	12.10	850	92	do	37.0
21	12.10			do	
22	12.00				
23	12.05				
24	12.00			Curve (7)	
25	11.90			do	
26	11.80			do	

TABULATION VII.—*Red River Landing-Carrollton equivalent gauge heights*—Continued.

Carrollton dates.	Carrollton gauge.	Carrollton discharge.	No. of observation.	Red River Landing plane.	Red River Landing equivalent gauge.	Carrollton dates.	Carrollton gauge.	Carrollton discharge.	No. of observation.	Red River Landing plane.	Red River Landing equivalent gauge.
1885.						1885.					
Feb. 27	11.75	....	......	Curve (7) .	......	Mar. 13	8.70	615	108	Curve (8) .	28.7
28	11.40	819	98	...do	35.8	14	8.80	616	109	...do	28.7
Mar. 1	11.35	....	......	...do	......	15	9.10	....	......	...do	......
2	11.15	743	99	...do	34.0	16	9.45	649	110	...do	29.6
3	10.85	717	100	...do	33.4	17	9.55	665	111	...do	30.0
4	10.70	682	101	...do	32.6	18	9.75	....	......	....	......
5	10.30	665	102	...do	32.1	19	9.90	684	113	Curve (9) .	31.6
6	9.90	....	......	....	......	20	10.15	705 t	114	...do	31.9
7	9.55	....	......	....	......	21	10.60	710	115	...do	32.0
8	9.10	....	......	....	......	22	10.70	....	......	...do	......
9	8.85	....	......	....	......	23	10.70	726	116	...do	32.4
10	8.70	621	106	Curve (8) .	28.9	24	10.90	740	117	...do	32.8
11	8.70	612 t	107	...do	28.7	25	11.00	....	......	....	......
12	8.70	....	......	...do	......	26	11.20	....	......	....	......

TABULATION VIII.—*Red River Landing normal curves, with the corresponding Carrollton equivalent gauge heights on the line of the equivalent gauge relation, giving the various Carrollton normal curves.*

Red River Landing gauge.	Carrollton equivalent gauge.	Values of discharge scaled on the various Red River Landing normal curves.						
		1	3	4	5	6	8	9
4..............	−1.47	123	....	....	....	....	....	....
6..............	−0.65	161	....	....	....	....	....	....
8..............	+0.18	203	....	....	....	....	....	....
10..............	1.00	247	....	....	....	....	....	....
12..............	1.82	298	....	....	....	....	....	....
14..............	2.65	351	....	....	....	....	....	....
16..............	3.47	410	....	....	....	....	....	....
18..............	4.29	473	....	....	....	....	....	....
20..............	5.12	540	....	....	....	....	....	....
22..............	5.94	611	....	....	....	....	....	....
24..............	6.76	690	478	....	....	375	....	....
26..............	7.59	773	548	508	463	434	520	....
28..............	8.41	860	619	577	530	500	589	557
30..............	9.23	953	697	651	601	571	663	631
32..............	10.06	1,051	780	732	678	645	746	708
34..............	10.88	1,155	868	816	760	723	....	793
36..............	11.71	1,266	962	906	847	807	....	883
38..............	12.53	1,384	1,062	1,002	940	899	....	....
40..............	13.35	1,505	....	1,104	1,039	996	....	....
42..............	14.16	....	....	1,211	1,142	1,097	....	....
44..............	15.00	....	....	....	1,249	1,201	....	....
46..............	15.82	....	....	....	....	....	....	....

TABULATION IX.—*Arkansas City-Vicksburg equivalent gauge heights.*

Red River Landing dates.	Vicksburg gauge.	Red River Landing discharge.	Number of observation.	Old River discharge.	Vicksburg approximate discharge.	Arkansas City plane.	Arkansas City equivalent gauge.
1884.							
Oct. 15	18.00	406	8	....	*480	Curve (1)	20.9
16	17.90	403	9	....	477	...do	20.8
17	17.55	395	10	....	463	...do	20.3
18	16.95	383	11	....	447	...do	19.7
19	16.45	377	....	....	430	...do	19.0
20	15.95	370	12	....	417	...do	18.5
21	15.70	368	13	....	407	...do	18.1
22	15.65	368	14	....	404	...do	18.0
23	15.75	368	....	....	410	...do	18.2
24	15.85	368	15	....	412	...do	18.3
25	15.85	370	16	....	412	...do	18.3
26	15.75	370	....	....	412	...do	18.3
27	15.55	368	....	....	407	...do	18.1
28	15.20	362	17	....	402	...do	17.9
29	15.00	360	....	....	394	...do	17.6
30	14.65	359	18	....	385	...do	17.2
31	14.25	355	19	....	376	...do	16.8
Nov. 1	13.95	346	20	....	366	...do	16.4
2	13.70	343	....	....	359	...do	16.1
3	13.65	340	....	....	357	...do	16.0
4	13.75	340	21	....	361	...do	16.2
5	13.90	343	22	....	368	...do	16.5
6	14.05	343	23	....	370	...do	16.6
7	13.85	340	24	....	368	...do	16.5
8	13.70	335	25	....	363	...do	16.3
9	13.60	332	....	....	361	...do	16.2
10	13.40	330	26	....	357	...do	16.0
11	13.10	321	27	....	351	...do	15.8
12	12.70	313	28	....	342	...do	15.4
13	12.15	303	29	....	328	...do	14.8
14	11.60	296	30	....	313	...do	14.1
15	10.95	291	31	....	307	....	13.6
16	10.30	286	....	....	298	....	13.0
17	9.75	281	32	....	289	....	12.3
18	9.20	276	33	....	280	....	11.8
19	8.70	271	34	....	270	....	11.3
20	8.20	268	35	....	263	....	10.8
21	7.70	258	36	....	260	....	10.4
22	7.20	251	....	....	256	....	10.0
23	6.90	251	....	....	255	....	9.6
24	6.50	245	37	....	252	Curve (2)	9.3
25	6.50	240	38	....	250	...do	9.2
26	6.30	237	39	....	247	...do	9.0
27	6.20	235	....	....	247	...do	9.0
28	6.10	235	40	....	247	...do	9.0
29	6.00	231	41	....	242	...do	8.8
30	5.90	229	....	....	241	...do	8.7
Dec. 1	5.80	226	42	....	239	...do	8.60
2	5.70	226	43	....	237	...do	8.50
3	5.90	221	44	....	239	...do	8.60
4	6.05	240	45	....	247	...do	9.00
5	6.95	257	....	....	252	...do	9.50
6	7.75	273	46	....	272	...do	10.30
7	8.45	280	....	....	287	...do	11.00
8	9.05	286	47	....	301	...do	11.70
9	9.05	286	48	....	305	...do	11.90
10	8.80	280	49	....	301	...do	11.70
11	8.30	273	....	....	287	...do	11.00
12	7.70	267	50	....	273	...do	10.40
13	7.00	253	51	....	260	...do	9.70
14	6.25	250	....	—4	254	...do	9.45
15	5.60	247	....	2	249	...do	9.10
16	5.10	235	52	0	235	...do	8.40
17	4.85	230	....	0	230	...do	8.15
18	5.10	237	....	2	239	...do	8.60
19	6.30	260	53	4	264	...do	9.95
20	8.30	293	54	8	301	...do	11.70
21	10.20	330	....	11	341	....	.....
1884.							
Dec. 22	12.05	348	55	14	362	....	.....
23	13.75	366	56	15	381	Curve (1)	17.00
24	14.85	386	57	15	401	...do	17.90
25	15.45	403	....	15	418	...do	18.50
26	15.75	413	....	15	428	...do	18.95
27	15.90	416	....	—8	424	...do	18.18
28	15.90	419	....	+1	418	...do	18.55
29	15.20	424	....	15	409	...do	18.15
30	14.60	435	59	40	395	...do	17.65
31	14.50	449	60	63	386	...do	17.20
1885.							
Jan. 1	15.15	468	....	+70	398	...do	17.75
2	15.50	485	61	68	417	...do	18.50
3	17.25	522	62	62	462	...do	20.25
4	20.40	560	....	53	507	...do	21.95
5	23.55	605	....	44	561	...do	23.85
6	25.90	684	....	30	654	...do	26.90
7	28.55	748	....	+17	731	...do	29.20
8	31.00	813	63	—2	815	...do	31.65
9	32.80	874	64	15	889	...do	33.65
10	34.20	895	65	20	915	....	.....
11	35.25	915	....	20	935	Curve (3)	36.25
12	36.05	935	....	21	956	...do	36.80
13	36.70	962	66	21	983	...do	37.45
14	37.25	982	....	22	1,004	...do	38.00
15	37.60	1,002	....	23	1,025	...do	38.50
16	37.95	1,027	....	27	1,054	...do	39.20
17	38.45	1,048	67	28	1,076	...do	39.70
18	39.10	1,062	....	25	1,087	...do	39.95
19	39.80	1,072	68	22	1,094	...do	40.10
20	40.20	1,094	....	17	1,111	...do	40.50
21	40.45	1,103	69	12	1,115	....	.....
22	40.70	1,115	70	—6	1,121	....	.....
23	41.00	1,118	....	0	1,118	....	.....
24	41.20	1,120	....	+5	1,115	....	.....
25	41.35	1,120	....	10	1,110	....	.....
26	41.70	1,120	71	13	1,107	....	.....
27	41.80	1,115	72	17	1,098	Curve (4)	41.80
28	41.90	1,120	....	20	1,100	...do	41.85
29	42.00	1,125	73	22	1,103	...do	41.90
30	42.00	1,130	74	25	1,105	...do	41.95
31	42.20	1,130	....	+28	1,102	...do	41.90
Feb. 1	42.20	1,135	....	+30	1,105	...do	41.95
2	42.25	1,135	75	31	1,104	...do	41.95
3	42.35	1,135	....	31	1,104	...do	41.95
4	42.35	1,135	76	32	1,103	...do	41.90
5	42.40	1,141	77	33	1,108	...do	42.00
6	42.30	1,135	78	34	1,101	....	.....
7	42.20	1,130	79	34	1,096	....	.....
8	41.80	1,115	....	35	1,080	Curve (5)	42.40
9	41.45	1,080	....	39	1,041	...do	41.45
10	40.70	1,062	80	45	1,017	...do	40.90
11	40.00	1,035	81	56	979	...do	39.95
12	39.00	1,020	82	69	951	...do	39.25
13	38.20	1,000	....	78	922	...do	38.50
14	37.40	981	83	83	898	...do	37.60
15	36.60	957	....	85	872	...do	37.20
16	36.00	937	84	85	852	...do	36.70
17	35.45	918	85	82	836	....	.....
18	34.90	899	....	78	821	....	.....
19	34.50	885	86	72	813	Curve (4)	34.60
20	34.20	875	87	69	806	...do	34.40
21	33.95	866	88	65	801	...do	34.25
22	33.90	867	....	61	806	...do	34.40
23	33.75	867	....	57	810	...do	34.50
24	33.45	863	89	55	808	...do	34.45
25	33.00	863	90	55	808	...do	34.45
26	32.70	846	....	61	785	...do	33.80

*To December 13, the Arkansas City Q's are taken as Vicksburg approximate Q's.

Tabulation IX.—*Arkansas City-Vicksburg equivalent gauge heights*—Continued.

Red River Landing dates.	Vicksburg gauge.	Red River Landing discharge.	Number of observation.	Old River discharge.	Vicksburg approximate discharge.	Arkansas City plane.	Arkansas City equivalent gauge.	Red River Landing dates.	Vicksburg gauge.	Red River Landing discharge.	Number of observation.	Old River discharge.	Vicksburg approximate discharge.	Arkansas City plane.	Arkansas City equivalent gauge.
1885.								1885.							
Feb. 27	32.20	824	91	71	753	Curve (4) .	32.90	Mar. 16	26.20	671	....	39	632	Curve (6) .	27.80
28	31.30	798	92	+85	713	...do	31.70	17	27.45	681	....	29	652	....	.....
Mar. 1	30.20	768	....	+96	672	...do	30.45	18	28.55	685	102	16	669	Curve (7) .	30.00
2	28.80	739	93	99	639	...do	29.40	19	29.45	709	103	+7	702	...do	31.00
3	27.50	708	94	100	608	...do	28.45	20	30.20	725	104	—3	728	...do	31.75
4	26.00	669	....	99	570	...do	27.15	21	30.85	750	105	11	761	...do	32.70
5	24.70	652	95	99	553	....	.....	22	31.50	775	....	14	789	...do	33.50
6	23.60	641	96	98	543	....	.....	23	32.20	785	106	18	803	...do	34.00
7	23.00	632	97	97	535	Curve (6) .	24.50	24	32.95	795	107	20	815	....	.....
8	22.60	625	....	95	530	...do	24.30	25	33.45	801	....	22	823	....	.....
9	22.45	621	98	92	529	...do	24.30	26	33.90	805	....	24	829	....	.....
10	22.45	610	....	90	520	...do	24.00	27	34.25	804	....	25	829	....	.....
11	22.70	606	99	83	523	...do	24.10	28	34.50	808	....	25	833	Curve (8) .	35.80
12	23.00	610	....	76	534	...do	24.50	29	34.60	811	....	24	835	...do	35.85
13	23.50	614	100	69	545	...do	24.90	30	34.60	811	108	—23	834	...do	35.85
14	24.25	629	101	60	569	...do	25.70	31	34.45	.....	....	....	.....	....	.....
15	25.05	649	....	51	598	...do	26.65								

Tabulation X.—*Arkansas City normal curves, with the corresponding Vicksburg equivalent gauge heights on the various lines of the equivalent gauge relation, giving the various Vicksburg normal curves.*

Arkansas City gauge.	Vicksburg equivalent gauge on lines.		Values of discharge scaled on the various Arkansas City normal curves.					
	1	2	1	2	3	4	5	6
4	0.66	1.36	128	158	....	....	....	....
6	2.79	3.49	160	191	....	....	....	....
8	4.91	5.61	193	227	....	....	....	....
10	7.04	7.74	229	266	....	....	....	....
12	9.17	9.87	269	307	....	....	....	....
14	11.30	12.00	310	352	....	....	....	....
16	13.43	14.13	356	400	....	....	....	....
18	15.56	16.26	404	451	....	....	....	....
20	17.69	18.39	454	505	....	....	....	....
22	19.81	20.51	509	....	....	420	402	....
24	21.94	22.64	566	....	527	481	453	521
26	24.07	24.77	626	....	583	536	507	578
28	26.20	26.90	691	....	645	595	563	639
30	28.33	29.03	759	....	710	657	624	703
32	30.46	31.16	829	....	779	724	689	772
34	32.59	33.29	903	....	850	792	756	843
36	34.71	35.41	983	....	926	865	827	919
38	36.84	37.54	1066	....	1005	942	902	998
40	38.97	39.67	1150	....	1090	1023	981	....
42	41.10	41.80	1241	....	1178	1107	1063	....
44	43.23	43.93	1336	....	1270	1196	1149	....
46	45.36	46.06	1435	....	1365	1288	1238	....

APPENDIX B.

PAPER BY LIEUTENANT-COLONEL CHAS. R. SUTER, CORPS OF ENGINEERS, ON EFFECTS OF CREVASSES UPON GAUGE READINGS BELOW RED RIVER DURING HIGH WATER OF 1890.

ST. LOUIS, MO., *March 16, 1891.*

GENERAL: As great interest was felt last year in the behavior of the Mississippi below the junction of the Red, and many conjectures were made as to the heights that would have been reached had no crevasses occurred, I have had the matter investigated as far as the data at my command would allow, and the conclusions reached are herewith submitted to the Commission.

In this investigation I have used the method of gauge relations, fully explained in previous papers, which is specially applicable in this case, owing to the short distance between the gauges and to the general regularity of the gauge records in this part of the river. As Red River Landing is below the last tributary of the Mississippi it was decided to take its gauge record as the standard with which the others should be compared. The plates herewith, numbered III and IV, give the gauge relations between Red River Landing and Bayou Sara, Baton Rouge and Carrollton. These diagrams show that the effect of the crevasse at Nita while apparent at Baton Rouge is barely perceptible at Bayou Sara, hence Red River must have been beyond its influence, and can safely be taken as the standard up to the period of the Morganza and other later breaks. These crevasses had a very marked effect at Red River, and are easily traced on the Natchez and St. Joseph hydrographs. Vicksburg was also apparently affected, but to such a small extent that it has been deemed possible to deduce the probable Red River Landing gauge heights, after the Morganza breaks, from the Vicksburg-Red River Landing gauge relation in the manner explained further on (Plate VIII). Other gauge relations are also given, viz, Bayou Sara-Baton Rouge, Plate V; Baton Rouge-Plaquemine, College Point, Plate VI; and Baton Rouge-Carrollton, Plate VII. This latter plate also shows the relations Plaquemine-College Point, and College Point-Carrollton. These various gauges are below Red River Landing and at the following distances therefrom: Bayou Sara, 34.2 miles; Baton Rouge, 68 miles; Plaquemine, 88.2 miles; College Point, 137.7 miles; Carrollton, 191.7 miles. The time intervals used in platting these gauge relations are indicated on the diagrams. The Nita Crevasse was about 4 miles above the College Point gauge, Morganza was 10 miles above Bayou Sara, the others, mostly small breaks, were near Baton Rouge. The straight lines drawn on these various diagrams give what seem the most probable relation between the different gauges for the period preceding the formation of the crevasses, and the assumption made is that if no crevasses had occurred this relation would have held to the top of the flood. The heights which would have been reached at the various gauges in order to correspond to the actual Red River Landing gauge readings can be scaled at once from the various diagrams given, and these deduced readings are shown by dotted lines on Plate I for each gauge, the actual hydrograph being indicated by a full line. After the Morganza breaks the Red River Landing probable readings have been deduced from Vicksburg, and also the corresponding elevations for points below. These elevations are shown by a series of dotted and dashed lines above the first, and extend some distance beyond the crest of the flood. To show the measure of accuracy to be expected by this method, the deduced readings are given from the beginning of the flood in January, 1890, for each gauge. On the diagram are also marked the dates of all crevasses with their measured discharge. It should be noted that this diagram is platted to Red River dates, time intervals, as already mentioned, being used for points below Red River Landing.

Plate VIII shows the Vicksburg-Red River Landing gauge relation; the line marked standard is the line giving this relation for equal discharges as determined by the 1884–'85 observations. The deviations from this line are no greater than might be reasonably anticipated from the tributary effect of Red River till March 15, when the Raleigh break produced a rapid fall at Vicksburg, Red River remaining about stationary. The return flow of the Yazoo seems to have begun about April 1, and the Vicksburg gauge rises again. About the same time the return flow from the Tensas at Red River Landing begins, and both gauges rise on a line considerably oblique to the standard. April 22 the Morganza breaks occurred and Red River fell rapidly, while Vicksburg continued to rise till the 25th, when it came to a stand, and so remained till the 27th, when it also began to fall. I infer that if the Morganza breaks had not occurred the two gauges would have risen on the line mentioned until the Vicksburg maximum had been reached, and would then have fallen on a line parallel to the one actually noted. Dotted lines show these probable relations, and from them the Red River Landing gauge heights are deduced and used in determining the elevations below. There were a few breaks between Vicksburg and Red River Landing, mainly near Natchez, which occurred about the same time as

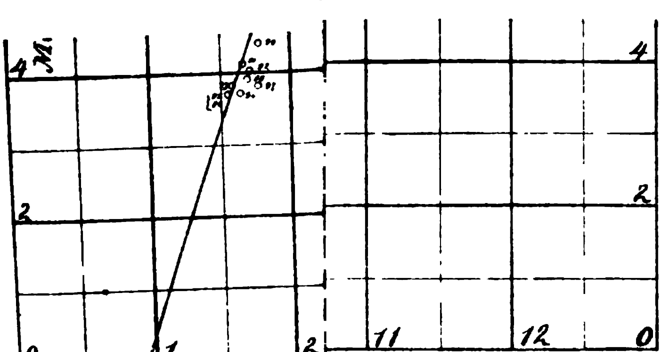

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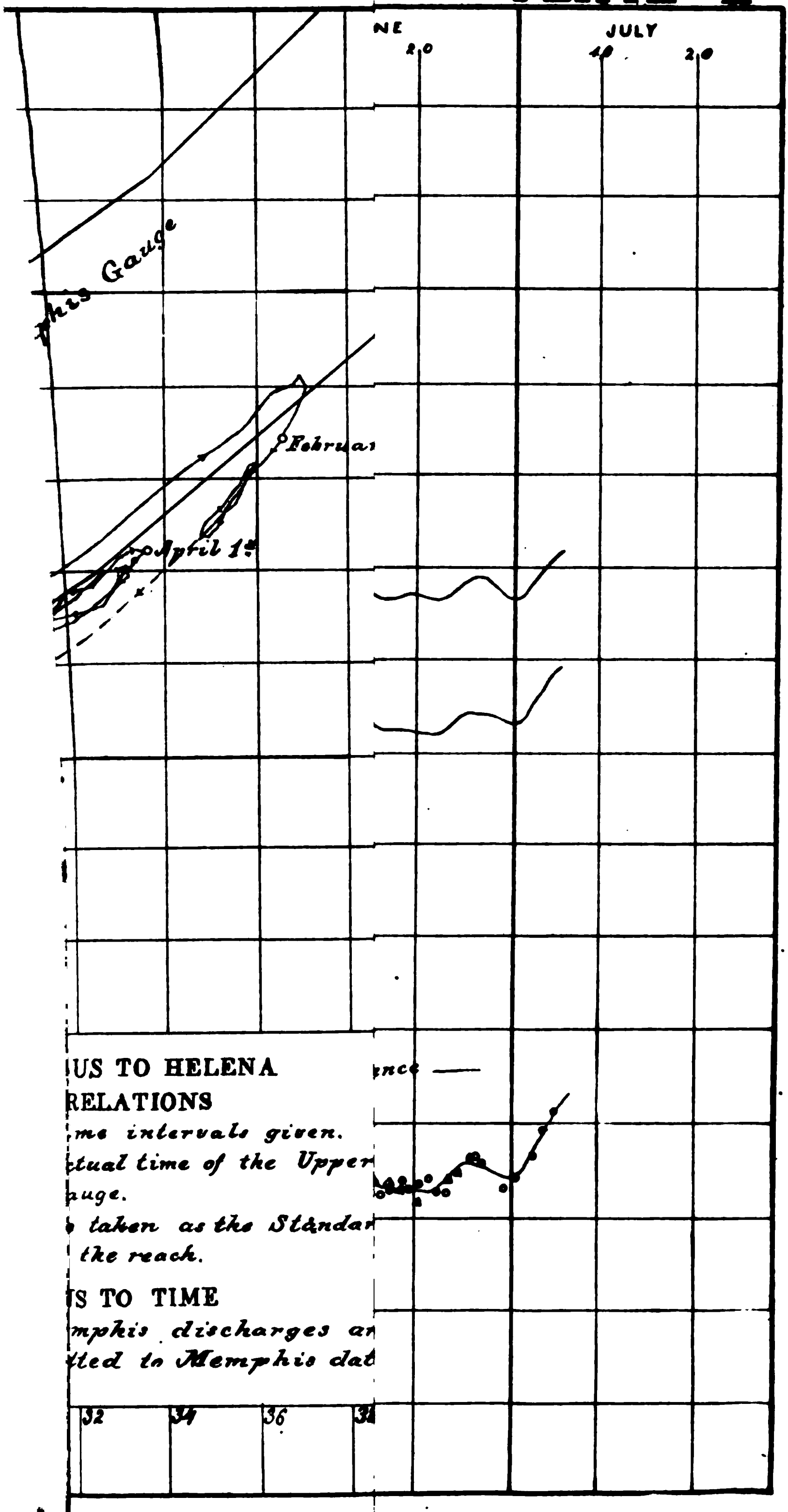
PLATE II

2


NE
JULY
20
10
20
his Gauge
Februa
April 1st
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US TO HELENA
RELATIONS
me intervals given.
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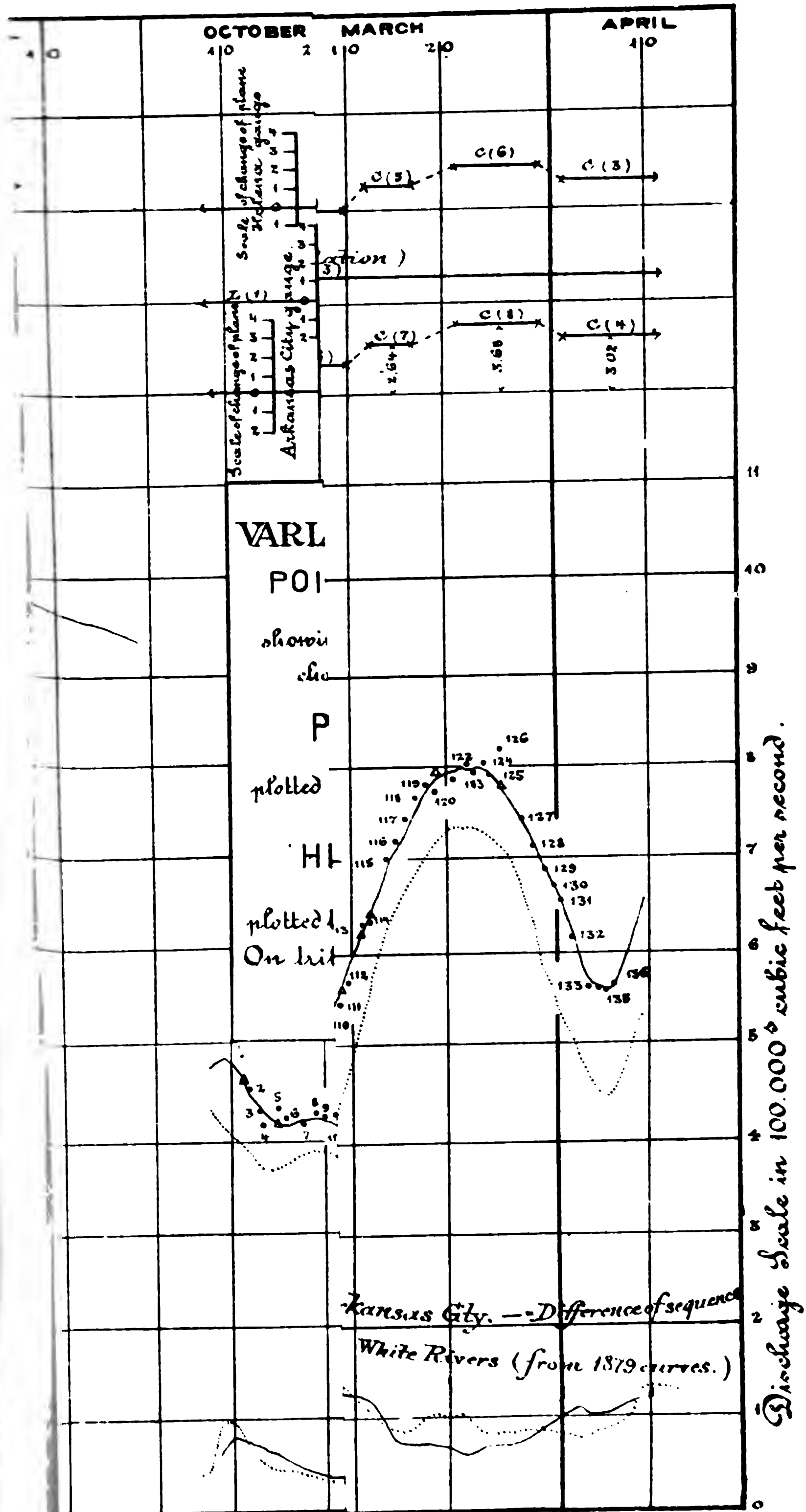
34
36

3


OCTOBER
MARCH
APRIL
Scale of change of plane Helena gauge
Arkansas City gauge
Scale of change of plane
C(5)
C(6)
C(3)
C(7)
C(8)
C(4)
VARI
POI
showi
P
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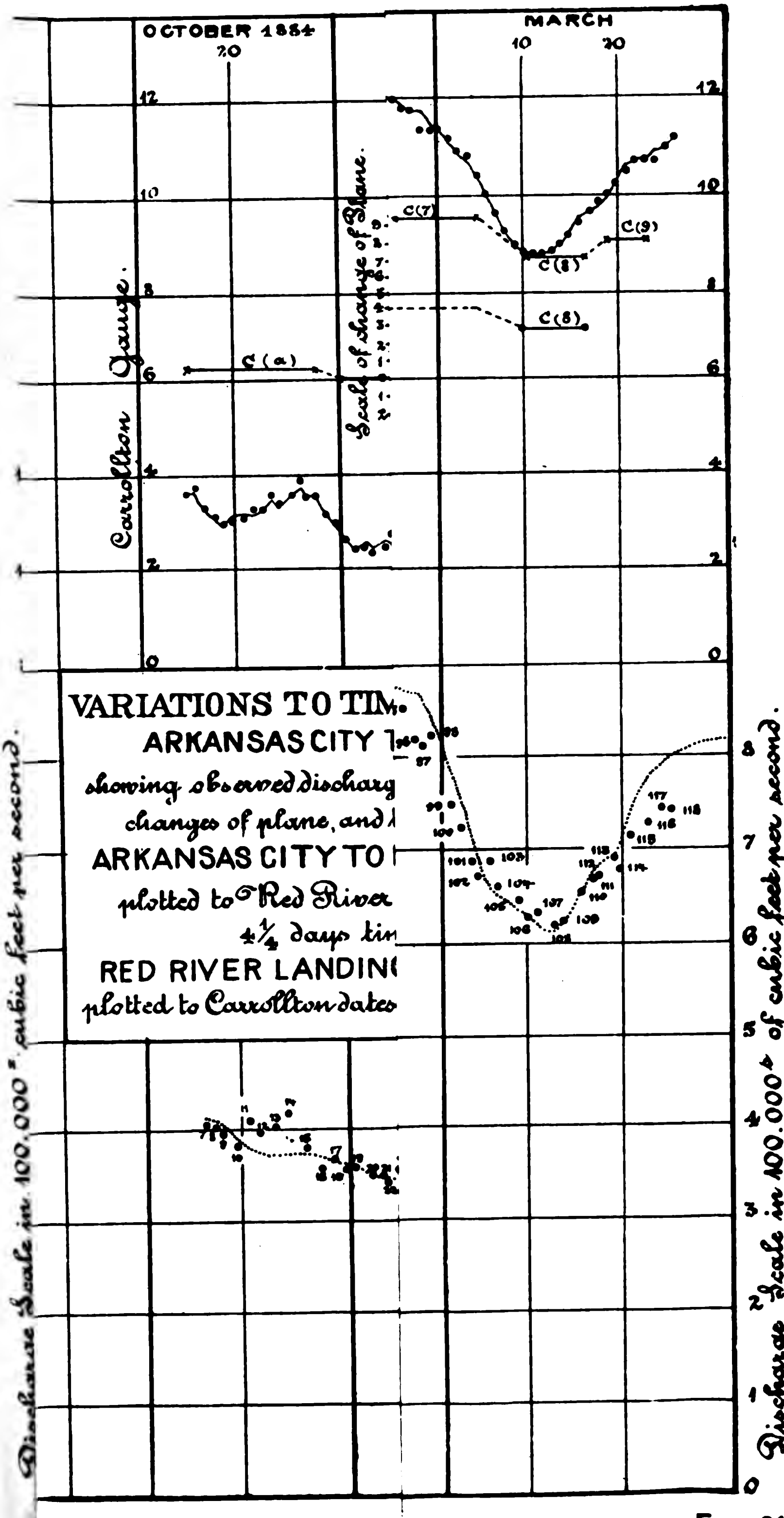
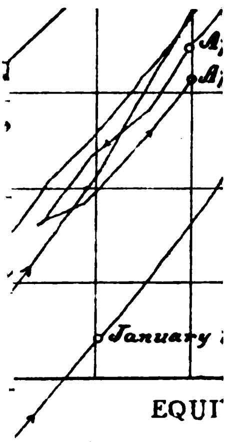
On lrit
Kansas City. — Difference of sequence
White Rivers (from 1879 curves.)
Discharge Scale in 100.000's cubic feet per second.


OCTOBER 1884
MARCH
Carrollton Gauge.
Scale of change of Plane.
C(7)
C(9)
C(8)
C(8)
C(a)
VARIATIONS TO TIM
ARKANSAS CITY T
showing observed discharg
changes of plane, and
ARKANSAS CITY TO
plotted to Red River
4¼ days tin
RED RIVER LANDIN
plotted to Carrollton dates
Discharge Scale in 100.000s cubic feet per second.
Discharge Scale in 100.000s of cubic feet per second.

5



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GAUGE

The Actual Gau
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On Equivalent
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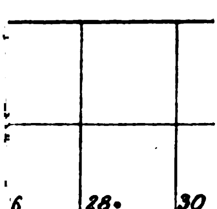
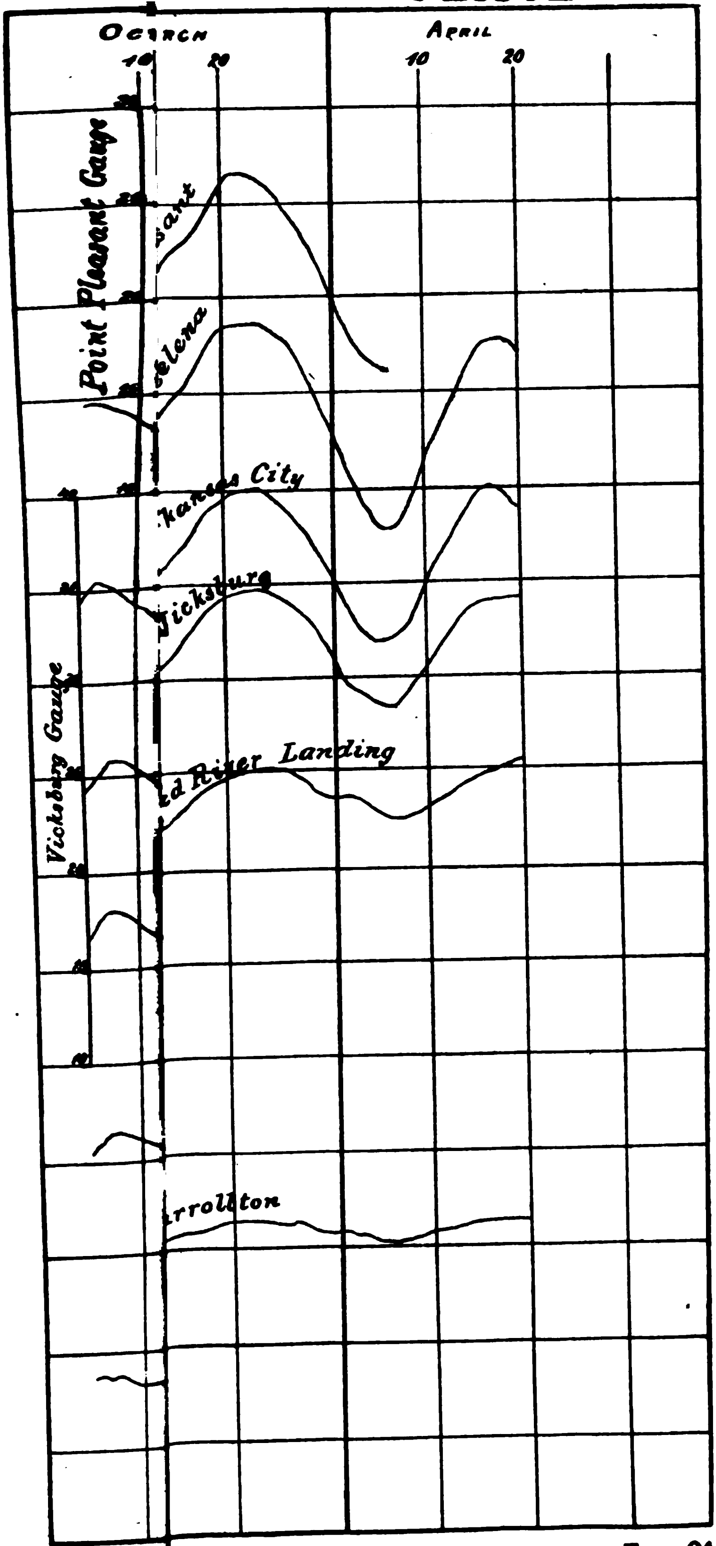
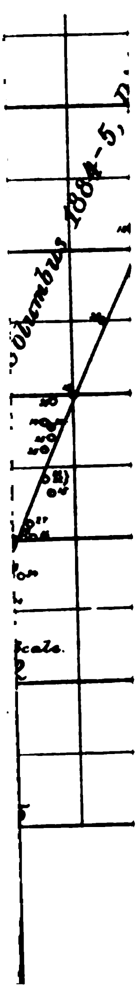
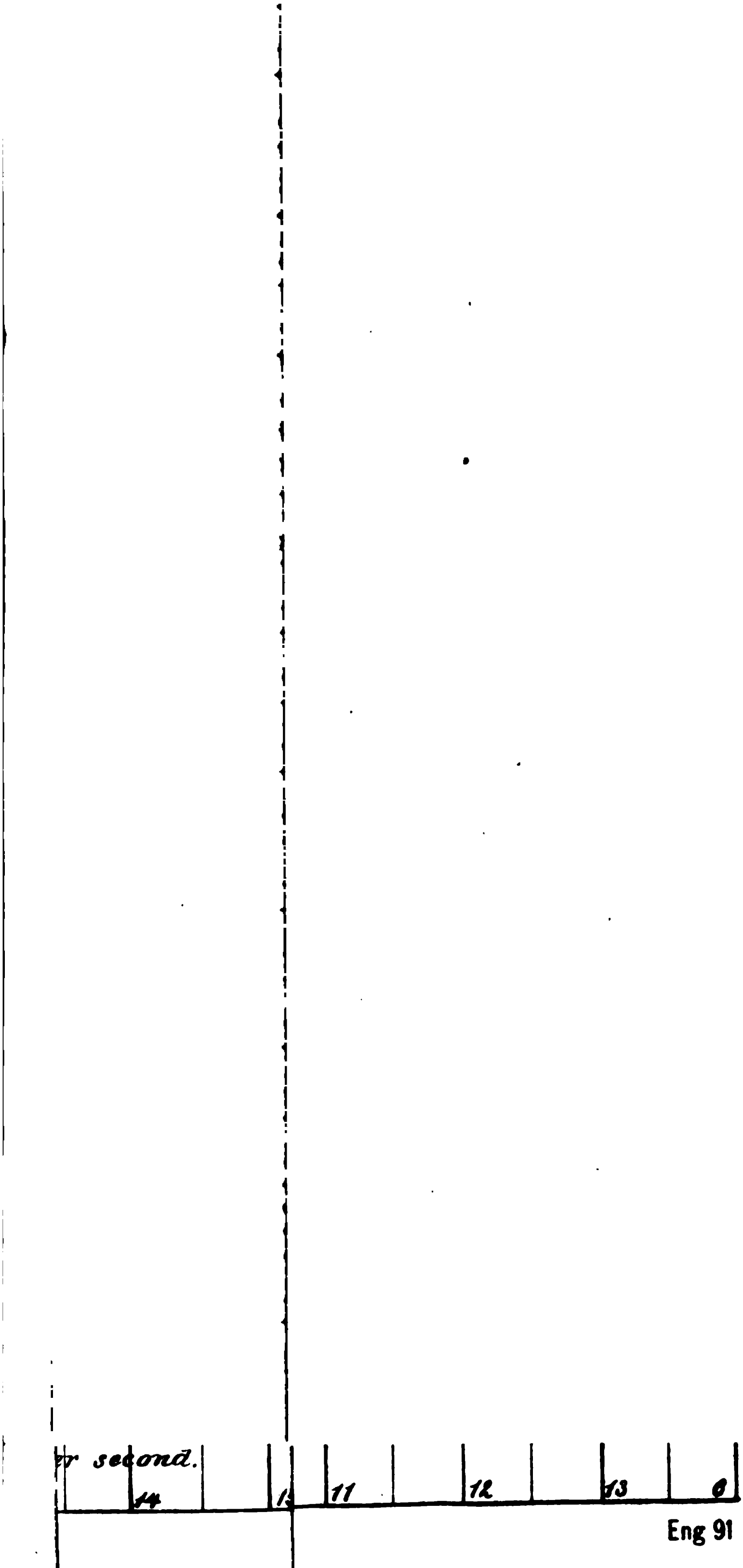


PLATE VI



April
10
20
Point Pleasant Gauge
Vicksburg Gauge
Kansas City
Vicksburg
Landing


1884-5,


r second.
14
11
12
13
0

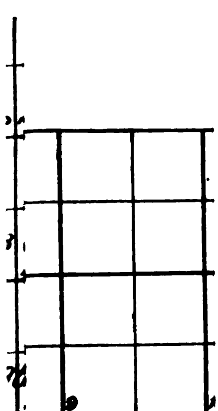
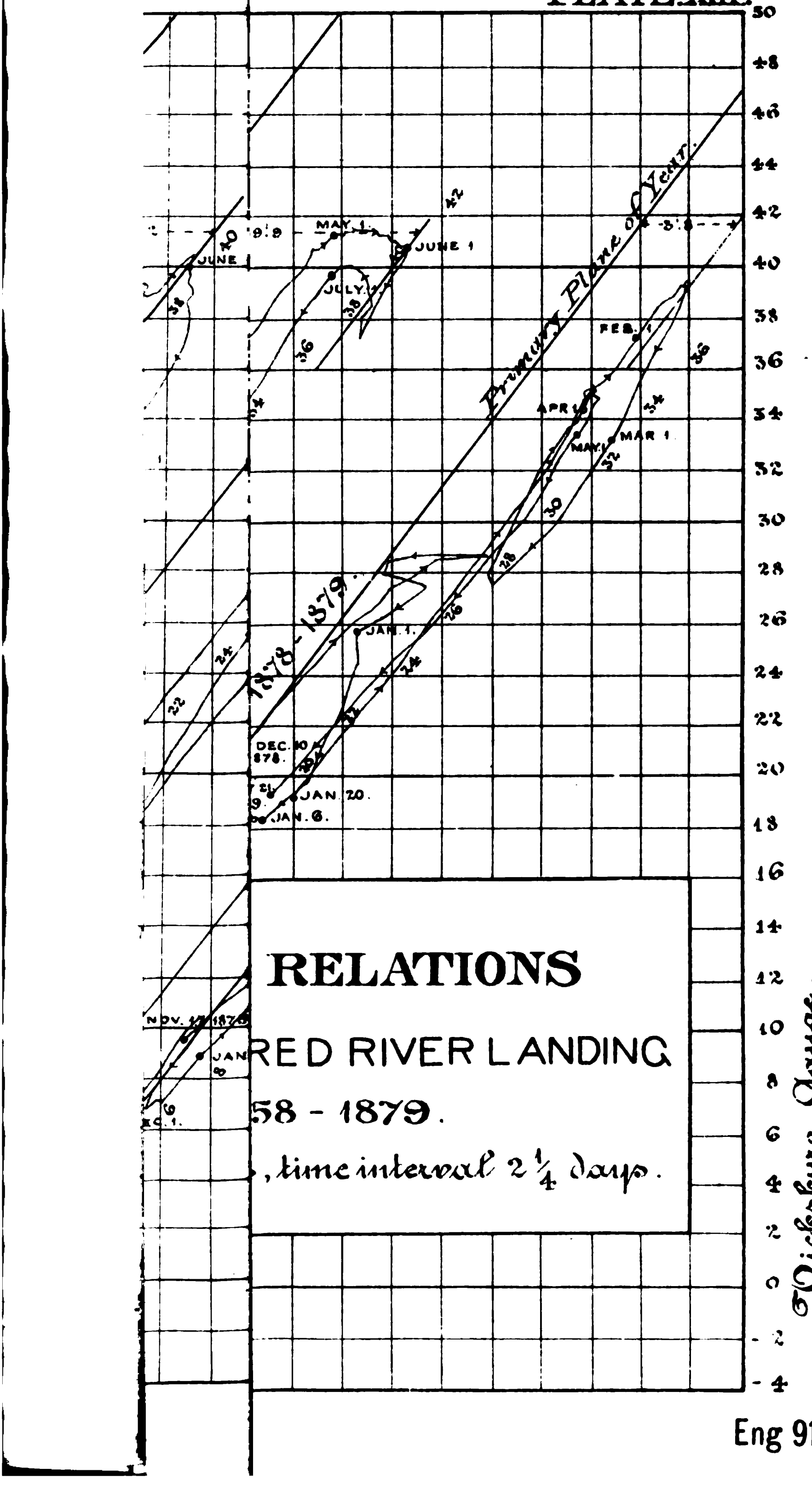
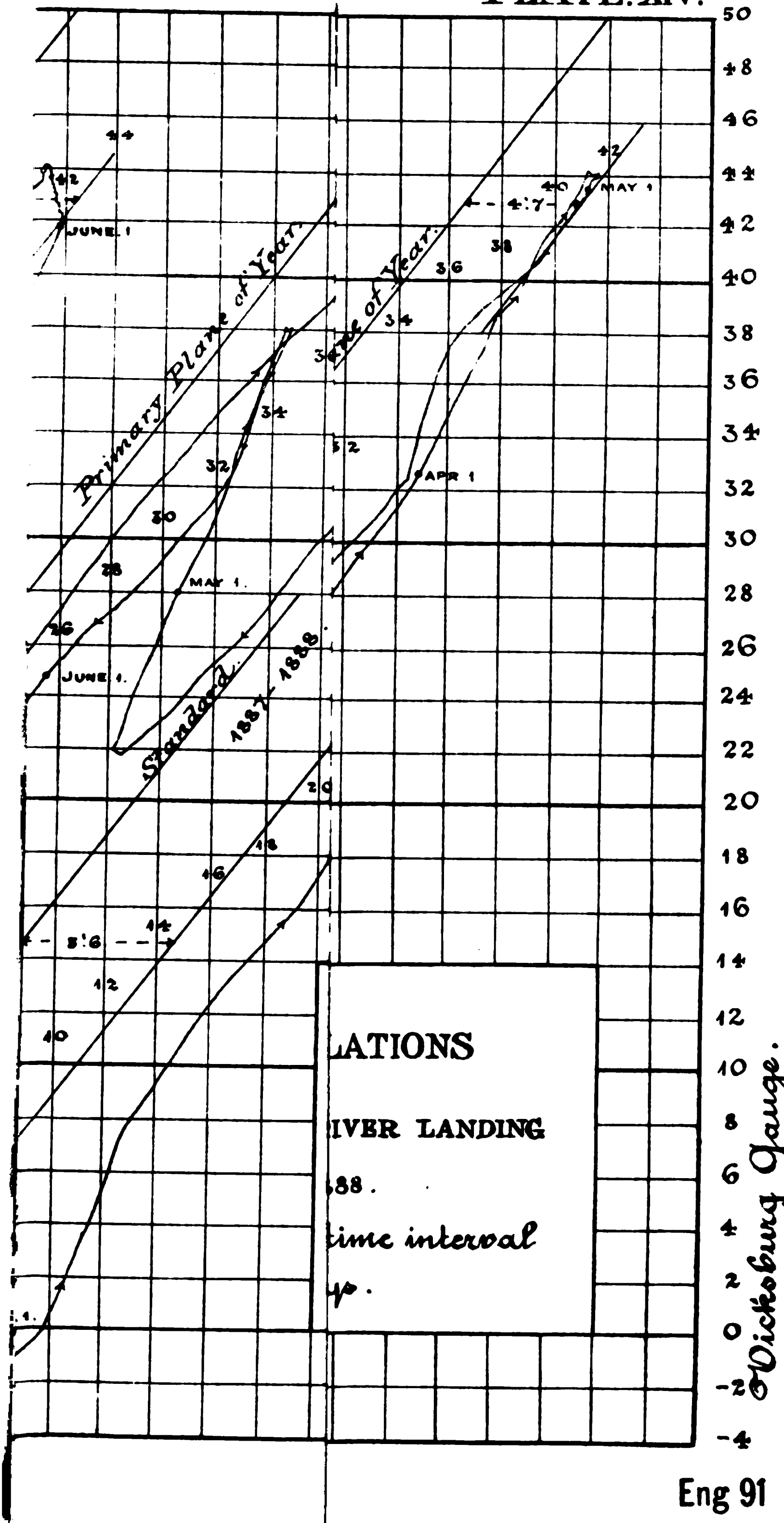


PLATE XIII.

13




LATIONS
IVER LANDING
388.
time interval
ys.
Primary Plane of Year.
Plane of Year.
Standard 1887-1888.
JUNE 1
MAY 1
APR 1
4.7
8.6
Vicksburg Gauge.
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
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18
16
14
12
10
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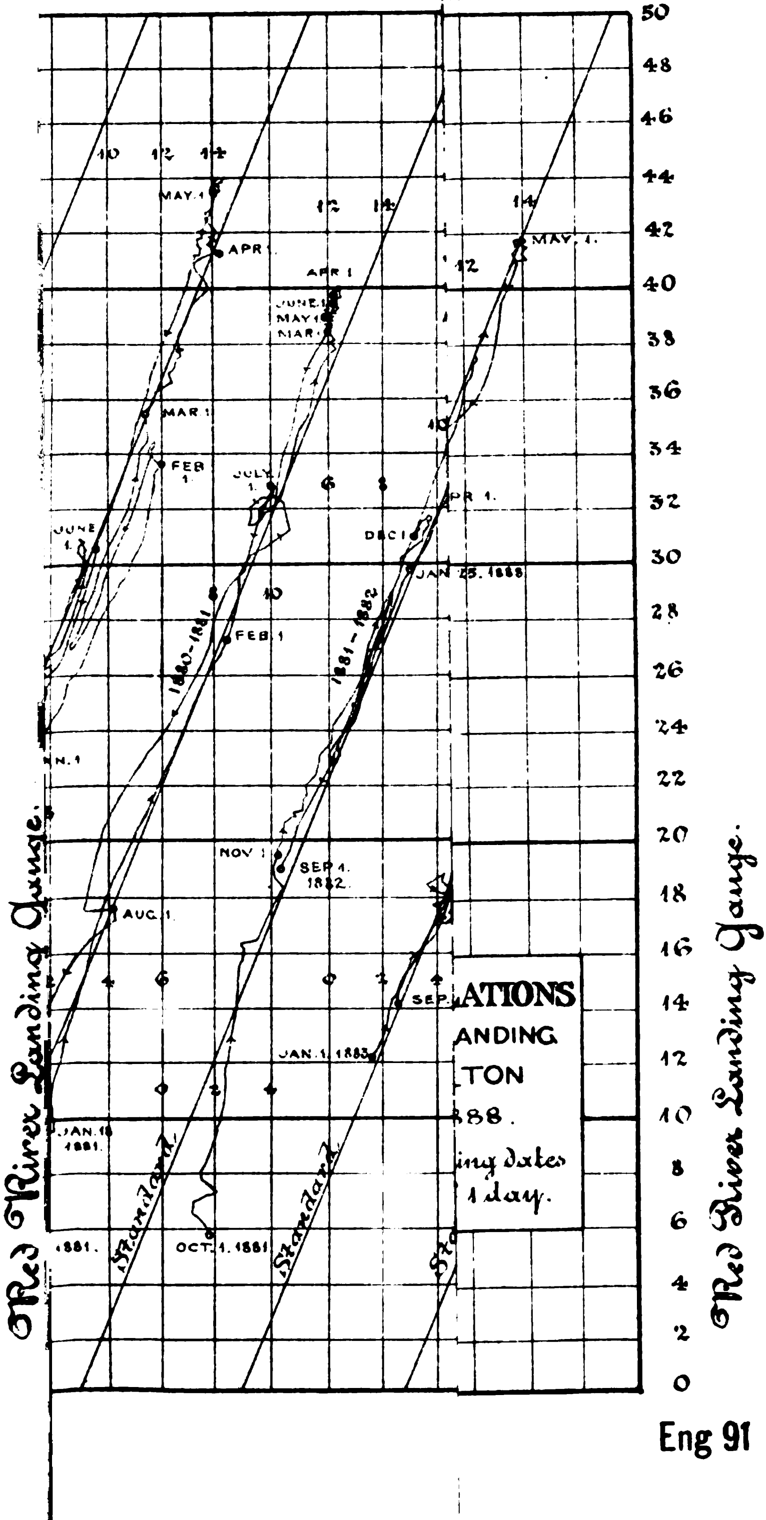
LATE XV.



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the Morganza, but it is probable that their effect at Red River Landing was small, as the water must have returned to the river almost immediately, and in any event the Morganza breaks, by drawing down the water surface at Red River Landing, must have considerably increased the return flow from the Tensas.

The gauge relation Red River Landing-Carrollton is about 0.6′ higher than the one which has heretofore held while the river has been confined between levees. No reason is known for this change nor whether it is permanent. It is, however, suggestive that a similar change occurred in 1880 after the low-flood year of 1879, while the flood of 1890 was preceded by the very low flood of 1889.

The following table gives the equivalent reading at the various gauges from which the lines of gauge relation here used can be reproduced.

Red River Landing.	Bayou Sara.	Baton Rouge.	Plaquemine.	College Point.	Carrollton.
Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
10.0	4.5	6.1	3.3	1.8	0.9
46.0	39.1	36.0	31.8	24.4	16.5

Plate II gives, in the shape of profiles, the same information as Plate I, the points where these profiles are taken being indicated by corresponding numbers on Plate I.

From this study I infer the following as the maximum heights which might have been reached had no crevasses occurred below Red River; they are given in tabular form, with the actual maxima reached in each case.

	Actual maximum.	Computed maximum.	Difference.
	Feet.	*Feet.*	*Feet.*
Red River Landing	48.67	49.0	+0.33
Bayou Sara	41.2	42.0	+0.8
Baton Rouge	36.6	38.5	+1.9
Plaquemine	31.9	34.2	+2.3
College Point	23.9	26.3	+2.4
Carrollton	16.1	17.85	+1.75

The effect of the enormous crevasse at Nita is also a matter of much interest. It can readily be deduced from the diagram on Plate I up to the dates of the Morganza and other breaks; after this time the combined effect of all the crevasses is shown. The maximum effect of the Nita while acting alone, and at a time when its discharge is estimated to have been between 300,000 and 400,000 cubic feet per second, is shown by the following table, the last column being the depression at each gauge due to the crevasse:

	Distance from crevasse.	Computed height without crevasse.	Actual height.	Difference.
	Miles.	*Feet.*	*Feet.*	*Feet.*
Red River Landing	*133.7	48.4	48.4	0.0
Bayou Sara	*99.5	41.4	41.2	(?) −0.2
Baton Rouge	*65.7	38.0	36.6	−1.4
Plaquemine	*45.5	23.8	31.9	−1.9
College Point	†4.0	25.9	22.4	−3.5
Carrollton	†58.0	17.55	15.4	−2.15

* Upstream. † Downstream.

Very respectfully, your obedient servant,

CHAS. R. SUTER,
Lieut. Col. of Engineers,
Member Mississippi River Commission.

Gen. C. B. COMSTOCK,
President Mississippi River Commission.

APPENDIX C.

REPORT OF THE SECRETARY, MISSISSIPPI RIVER COMMISSION.

This office was under charge of Capt. Charles F. Powell, Corps of Engineers, until October 15, 1890, when I relieved him in accordance with Special Orders No. 223, Headquarters Army, dated Washington, D. C., September 23, 1890.

The offices of secretary of the Mississippi River Commission and of assistant to construction committee date from the earlier operations of the Commission. The charge of surveys of Mississippi River under act of Congress approved August 11, 1888, was given to the secretary. The two offices remained separate in place and in organization, though for a time under charge of the same officer, till February, 1890, when, with saving of office expense, they were joined in place, remaining mainly distinct in organization. During the fiscal year a complete consolidation has been effected with further saving in clerical expense.

The works are now carried on under the following allotments from the appropriations approved September 19, 1890, and March 3, 1891, made by the Commission and approved by the honorable the Secretary of War: Mississippi River Commission; surveys, gauges, and observations; general service.

The allotment for Mississippi River Commission is applicable to salaries of three Commissioners, and to expenses of offices and of inspections. All property formerly held under appropriations for the Commission which is suitable for the works under the latter two allotments has been transferred to them.

The small balances from earlier appropriations which appear in the financial statement are set off by outstanding liabilities for telegrams which can not under existing orders be adjusted.

MISSISSIPPI RIVER COMMISSION.

At the beginning of the fiscal year, the salaries of the three Commissioners not otherwise in the service of the United States were in arrears since April 19, 1890.

An appropriation approved September 30, 1890, provided for the deficiency up to the beginning of this fiscal year, and another approved March 3, 1891, for that up to the date of the current regular appropriation; these have been applied to that purpose.

The Commission has held three sessions during the fiscal year: At New York City, October 1-4, 1890; from St. Louis to New Orleans, November 18-30, 1890; from St. Louis to New Orleans, March 17-24, 1891.

The following papers presented to the Commission are, in accordance with their resolution, appended hereto:

1. A measurement of the depression of the flood line 1890, at gauge stations below Red River Landing, from contiguous crevasses. By Capt. Charles F. Powell, Corps of Engineers (marked 1).
2. Statement of investigation and discussion of effects of outlets on the bed of the river below them, by Capt. Charles F. Powell, Corps of Engineers (marked 2).

SURVEYS, GAUGES, AND OBSERVATIONS.

Field work.—At the beginning of the fiscal year the work completed under the Mississippi River Commission was as follows:

Triangulation, from Donaldsonville, La., to Keokuk, Iowa.

Topography, from Donaldsonville, La., to Alton, Ill.

Precise levels, from Biloxi, Miss., to Savanna, Ill., and thence to Chicago, Ill., connecting with Lake Michigan.

No work of general survey had been carried on since season of 1889.

On March 15 Assistant Engineer F. B. Maltby was sent out on preliminary reconnoissance for triangulation, which was carried to Rapids City, a distance of about 144 miles, closing on April 23.

On April 25 a triangulation party under Assistant Engineer Charles W. Stewart, assisted by Assistant Engineers F. B. Maltby, A. T. Morrow, and George H. French, was sent out, beginning operations on April 28, at the base line established near Keokuk, Iowa, in May, 1881. This party was also charged with the establishment of lines of permanent bench-marks across the valley at intervals of about 3 miles, as hitherto placed in surveys under the Commission.

The triangulation has been carried as far as 4 miles above Burlington, Iowa, a distance of about 50 miles.

Number of stations occupied, 31.

Number of triangulation points marked, 34.

Number of bench-marks located, 61, marking 19 stone lines.

On April 25 a double precise level party under Assistant Engineer O. W. Ferguson, assisted by Assistant Engineer L. M. Mann, was sent out. Mr. Mann was obliged to leave the party on account of sickness, and has been replaced by Assistant Engineer A. L. Johnson. They began operations at St. Paul, Minn., on May 2, working southward along the river. The line has been carried as far as Alma, Wis.

Number of miles run, 95 (by river).

Number of permanent bench-marks established, 48.

Connection has been made with gauges at St. Paul., Minn., Hastings and Redwing, Minn., and with eleven bench-marks of earlier U. S. Engineer surveys.

On April 26 a single precise level party under Assistant Engineer James A. Paige was sent out. It began operations at Duluth, Minn., working towards St. Paul, Minn.

Number of miles run, 54.

Number of permanent bench-marks established, 12.

Connection was made with U. S. Engineer gauge at Duluth.

Copy of the instructions to these parties, and to the topographical parties which will take the field about August 1, is appended (marked 3).

Drawings and specifications of the permanent marks are also appended (Plate 6).

The above parties were inspected in the field by Assistant Engineer J. A. Ockerson, June 5–12.

Manuscript charts, etc., detail charts, scale 1: 10,000.—At the beginning of the fiscal year, these charts were completed (except titles and notes) from Donaldsonville, La., to Chester, Ill.; six sheets extending to St. Genevieve were in progress. This work is now completed (except titles and notes) as far as St. Louis; two sheets, extending to Alton, Ill., and covering the field hitherto topographically surveyed, are projected and outlined.

Topographical maps (scale 1 inch: 1 mile).—At the beginning of the fiscal year these maps were completed as far as Cairo, Ill.; one sheet extending 47½ miles by river was in progress. This work is now completed to 6 miles above Chester, Ill. (126 miles by river above Cairo); one sheet extending to 148 miles by river above Cairo is in progress.

The profile of Mississippi River, Cairo-Donaldsonville, has been completed showing right bank and levees from Cairo to Donaldsonville, left bank and levees from Memphis to Vicksburg, mean high and low water lines 1872–1889, and by points, the mean high and low waters 1881–1885, the high waters of 1882 and of 1890, the low water of 1883, and the lowest water of the period 1872–1890. A copy, in five sheets, with report of Assistant Engineer Ockerson, is herewith presented (marked 4, and plates 2, 3, 4, 5, 6).

Published charts and maps.—The charts and maps published by the Commission are the following; except official issues under resolution of the Commission, they are, in accordance with law, sold at the prices annexed. The publication of the first is completed; that of the others is in progress.

		Cents.
Alluvial valley (scale, 1 inch: 5 miles)	per sheet	10
Alluvial valley (scale, 1 inch: 5 miles)	per set (8 sheets)	40
Mississippi River (scale 1: 20,000)	per sheet	20
Mississippi River (scale, 1 inch: 1 mile)	per sheet	5

At the beginning of the fiscal year, of the charts on scale 1: 20,000, 56 sheets were published and 15 were in hands of the printer. These extended from Donaldsonville, La., to Cape Girardeau, Mo.; the published sheets were not consecutive.

This series is now published consecutively as far as Cape Girardeau, 71 sheets, and original material returned by printer. The material for 6 sheets, extending to Chester, Ill., is in hands of the printer.

At the beginning of the fiscal year the maps on scale of 1 inch: 1 mile were published as far as Cairo in 32 sheets with index chart, 3 sheets, and table of distances, 1 sheet. Drawings for revised edition of 10 sheets were in hands of printer.

The edition of these sheets is en route from Boston (shipped on June 19).

All of the above maps have required three or four proof-readings.

There have been issued during the fiscal year:

	Sheets.
lluvial valley	462
ale 1: 20,000	3,613
ale, 1 inch: 1 mile	1,794

Physical data.—In accordance with resolution of the Commission, November 27, the nge at Grays Point has been reëstablished.

The section of the old gauge from the 19-foot stage to the 35.7-foot stage was und intact, and is retained.

The section below the 19-foot stage, which was not in line with that above, had n destroyed, except one piece, 10-foot to 13-foot stage. This section had been

bolted to a rough rock, upon which it had bearing only at intervals, the bays being filled in with cement. For the new section replacing this a channel has been cut in the ledge. It has nearly continuous bearing, and is further protected by the shoulders of the channel. No filling in the small bays is believed to be necessary.

This section extends from the 3-foot stage to the 23-foot. It is graduated from the 5.5-foot stage, which was that of the water when the graduation was made.

The bulletin board has been repaired.

Recomputation of discharge measurements during 1887–1889 and 1890 has been completed. The results are appended (marked 5 and 6). A portion of each was published in the last Annual Report.

Field notes of discharge measurements in 1891 have been received from first, second, and third districts. Recomputation is in progress.

The records of gauges under the Commission, as also of certain others under the Chief Signal Officer, and Major Mackenzie and Captains Willard and Taber, Corps of Engineers, have been received, tabulated, and printed in pamphlet form, together with descriptions of gauges and bench-marks revised to date. For the description of bench-marks, important information has been received from Capt. J. H. Willard, Corps of Engineers.

Tables of high-water marks for 1890 and 1891, and of highest and lowest gauge readings revised to date, have been prepared and are hereto appended (marked 7, 8, and 9).

A hydrograph, showing stages of the Mississippi River and principal tributaries from St. Louis to Carrollton, by 10-day means for about 20 years, has been prepared, chiefly by Assistant Engineer L. M. Mann. Three sheets, with index map, are appended. (Not printed.)

An investigation of changes of depth of Mississippi River at Head of Passes, based upon published reports of Assistant Engineer Donovan, has been made by Assistant Engineer Ockerson. His report, with plat showing locations of sections, is appended (marked 10).

Current gauge records and office hydrographs have been kept up to date.

Card indices to manuscript reports and map files, in progress at beginning of fiscal year, have been completed and kept up to date.

Index to proceedings of Commission to include 1890 is ready for the printer.

Twenty-eight days' labor of office employés, costing $116, has been expended in preparing table of errata in last Annual Report as published.

Plant.—The plant held under this allotment, mostly received by transfer from Mississippi River Commission, consists of the survey fleet (1 steamboat, 2 quarter boats, 1 launch, and 13 rowboats), the field and office instruments, the printing plant, and office furniture.

The fleet, which had been laid up at Alton, Ill., was, on December 26, towed to Carondelet and hauled out for examination and repair.

The *Patrol* (8 years old) had her upper works in good order; the hull had been considerably patched above the water line at various times up to 1889; the bottom and much of the framing was badly decayed and worn. She has been thoroughly repaired, and is probably good for 4 or 5 years of service.

The quarter boats *Illinois* and *Kentucky* (8 years old) are slightly framed and cheaply built; they had had little repair and were in about the same condition as the *Patrol*, but offered less good work as a basis for repair. They have been repaired as far as their value appeared to warrant; the *Illinois* is probably good for 2 years' service, the *Kentucky* for one.

The launch has been transferred to the fourth district.

The boiler of the *Patrol* was tested on April 24.

On April 25, the *Patrol* with quarter boats *Illinois* and *Kentucky* in tow, and triangulation and double precise level parties on board, left St. Louis for St. Paul. The quarter boat *Illinois* with triangulation party was left at Nashville, Iowa, on the evening of April 27. The *Kentucky* with double precise level party was left at St. Paul on May 1, the *Patrol* then returning to the triangulation party for service during the season.

The field instruments have been repaired. Most of them have been in service many years. The important repairs consisted of returning spindles, trueing plates, and, in one case, regraduation of verniers. All are now in good condition.

GENERAL SERVICE.

Stone supply.—As soon as funds were available riprap stone was called for from the districts.

The total purchase on this call was:

	Location.	Riprap stone.
		Cubic yards.
First district	Osceola	3,717
Second district	Hopefield	1,132
Third district	Ashbrook	10,150
Lost en route		286
Total		15,285

The total mileage and yard mileage were:

	Miles.	Yard miles.
First district	6,002	341,864
Second district	4,368	880,185
Third district	28,453	5,183,808
Total	38,823	6,405,857

The total expense of delivery (not including repair of plant nor interest on its value) was $12,197.28 or 1.9 mills per yard mile.

The stone was delivered on the barges at the quarry for 65 cents per yard. Its transportation cost:

	Cents.
At Osceola	45.1
At Hopefield	57.4
At Ashbrook	98.3

The unfavorable circumstances of this towing materially increased its cost. Owing to the stage of the river barges were loaded to little over half their capacity, and, at the end of the work, had to be taken in small tows to Cairo, because the channel had become narrow and winding and there was danger of freezing in at the quarry. Owing to the urgent needs of the works deliveries were made in smaller tows than are economical.

Because of the difficulty, expense, and risk of this late towing, the officer in charge of first, second, and third districts decided to use at Osceola stone left over from the work at Hickman. The quarter boat (which had been brought to Cairo with last tow) with nine barges was taken to Hickman, January 5. On January 10 a steamer was sent from Cairo to tow two barge loads of this stone, which was delivered at Osceola on January 13. The loading was completed on January 31.

For the work of the next low-water season stone is now being supplied to the districts. This is purchased from the Apple Creek Quarry at 62½ cents per cubic yard, delivered on United States barges at quarry, and from the Grafton Quarry at 83 cents per cubic yard, delivered on United States barges at Cairo, Ill.; the two prices, considering the cost of towing, are accounted to be the same.

From the position of the quarries, the higher stages of the river are unfavorable for quarrying at Apple Creek, and the delivery there has been slow. The purchase at Grafton was made after delivery began to save time and to utilize the whole plant available.

The amount delivered and en route on June 30 is 19,402 cubic yards.

Plant.—At the beginning of the fiscal year the plant of the general service consisted of 3 towboats, 81 stone barges, 6 fuel barges, 1 store boat, 9 rowboats, 1 calking flat.

Of the towboats, the *Mississippi* (8 years old) was in good condition, having had ıparatively little service, and having been kept up by small repairs, no general ɐir had been made for 5 years. The *Minnetonka* (6 years old) had been thoroughly rhauled during the fiscal year 1890. The *Vedette* was under repair.

ıe stone barges are of four classes. Thirty (2 years old or less), 120 by 30 by 7 , framed, bottom planked fore and aft, flush decks, were in good condition, needɔnly calking. Twenty-seven (8 years old), 120 by 30 by 6 feet, gunwaled, bot- planked athwartships, sunk decks, were in bad condition, needing general re- : or rebuilding in deck and sides; of these, one had been rebuilt and one cut down rebuilding in fiscal year 1890. Twenty-four (8 years old), 100 by 25 by 5 feet, waled, bottom planked athwartship, flush decks, condition as of last class; of se, two carry cabins of former survey boats, and are used as quarter boats, one ries two old cabins retained in the chance of their being of service.

The six fuel barges (3 years old), 120 by 25 by 6 feet, framed and without deck, were in good condition.

The store boat, an old coal barge, bought second-hand in 1885 and covered with a lightly framed storehouse, was in poor condition.

One towboat, the *Emma Etheridge*, built for the general service in 1882 and transferred to the third district in 1884, has been received by transfer from that district.

One barge, of second class, has been lost while towing during low water. The method of planking used in this class makes any grounding dangerous.

One small camel dock, capable of lifting one end of a barge only, on hand at beginning of the fiscal year, has been enlarged and two others built. With the three any barge in use in the general service can be lifted for calking the bottom.

The fleet, which had been laid up at Paducah, Ky., was, at the end of November, transferred to Cairo, Ill., where it now lies. No water front at either place is controlled by the Commission. No rent has been paid.

The towboats, including the *Etheridge*, have all received general repairs, and are now in good condition, except the *Mississippi*, which was injured by a snag in April, 1891 (though not so as to impair her running power), and is also in need of some general repair.

The barges are all in good condition. Two have been rebuilt from the water line. Seventy, in use in the districts from 6 months to 2 years, have been received back and thoroughly repaired; they had suffered more from lack of cleaning and ventilation than from service. Of those of the second and third class, 8 years old, the sides were much decayed; 6 were repaired by graving pieces; 30 were so much decayed as to make this method very expensive, and of doubtful expediency as regards their strength, and these were sheathed. Three, which had been fitted for mooring barges, have remained in the districts; they are reported as serviceable.

Three model barges belonging to the third district have also been repaired; six are under repair.

The camel docks cost $1,615. They have lifted 48 barges. The docking fees alone for this service, even if several were docked at once, would have been $1,680, besides which the cost of labor and supervision at the dockyards is materially increased.

Little further repair, except to the *Mississippi*, is expected during the fiscal year.

TONNAGE OF THE RIVER.

The traffic on the sections of the Mississippi River under charge of the Commission is mainly carried on by lines of steamers and barges plying from St. Louis, Cincinnati, and Pittsburg to New Orleans and intermediate landings, the upstream loads being light. The custom-house records are of registered tonnage only. A statement is appended.

The Merchants' Exchange of St. Louis keeps, by calendar years, minute record of shipments and record of receipts in bulk. As freights from the upper river are reshipped here, this represents the northern traffic. Statements of shipments by New Orleans boats and by Memphis, Vicksburg, and Natchez boats, taken from their last annual statement, are appended. The last-mentioned line makes landings above the mouth of the Ohio; one-fourth of their shipments is deducted in preparing the table of commercial statistics for this report. The most important shipment from St. Louis is of grain in bulk for exportation; a detailed statement of this shipment from the Merchants' Exchange is appended. This line of traffic was closed to all heavy draft after December 13 on account of low water. It has not been obstructed by ice during the year.

The reports of shipments from the Ohio River are incomplete. Information has been sought from the owners of registered steamers, from the board of trade, and the coal exchange of Pittsburg. Reports have been received from owners of almost half the registered tonnage; the estimate is made up proportionally.

Reports of local traffic are from reports of the district officers:

	First and Second districts.	Third district.	Fourth district.
	Tons.	*Tons.*	*Tons.*
Mississippi	740,709	743,346	659,2
Ohio	1,444,164	1,397,461	1,337,3.
Local	79,829	219,497	....
Total	2,294,702	2,360,304	....

Respectfully submitted.

CARL F. PALFREY,
Capt. of Engineers.

To the PRESIDENT MISSISSIPPI RIVER COMMISSION.

List of civilian engineers employed on work of river and harbor improvements in charge of Capt. Carl F. Palfrey, Corps of Engineers, to June 30, 1891, inclusive.

Name and residence.	Time employed.		Compensation.	Where employed.	Work on which employed.
	m.	d.			
H. W. Baker, Tacoma, Wash		26	$175	St. Louis, Mo	Construction of plant (G. S.).
C. M. Winchell, Washington, Ind		26	175	...do	Surveys (S. G. O.).
Kivas Tully, St. Louis, Mo	12		175	...do	In charge computations (S. G. O.).
C. W. Clark, St. Louis, Mo	12		175	...do	Platting maps (S. G. O.).
J. A. Ockerson, St. Louis, Mo	2		225	...do	In charge surveys (S. G. O.).
Do	9		250	...do	Do.
O. W. Ferguson, Chicago, Ill	2	11	175	In the field	Surveys.
Charles W. Stewart, Chicago, Ill	2	4	150	...do	Do.
James A. Paige, Sedalia, Mo	2	6	150	...do	Do.
F. B. Maltby, Chicago, Ill	3		140	...do	Do.
L. M. Mann, Milwaukee, Wis	1	3	125	...do	Do.
A. T. Morrow, Marion, Ind	2		125	...do	Do.
A. L. Johnson, St. Louis, Mo	1	2	125	...do	Do.
George H. French, Milton, Ill	2	6	120	...do	Do.

Approximate value of plant belonging to the United States and used in improving Mississippi River from the head of the Passes to the mouth of the Ohio River.

Allotment.	Class of property.	No.	Approximate value May 31, 1891.
Mississippi River Commission	Furniture	....	$100
Surveys, gauges, and observations	Steamboat *Patrol* with outfit	1	12,000
	Quarter boats with outfit	2	2,500
	Rowboats	13	175
	Surveying instruments	....	12,500
	Current meters	....	1,250
	Drawing instruments	....	750
	General tools	....	500
	Printing plant	....	750
	Office furniture	....	600
General service	Steamboat *Mississippi* with outfit	1	45,000
	Steamboat *Minnetonka* with outfit	1	30,000
	Steamboat *Emma Etheridge* with outfit.	1	13,500
	Steamboat *Vedette* with outfit	1	4,750
	Stone barges:		
	First class	30	66,300
	Second class	26	41,200
	Third class	24	22,800
	Fuel barges	6	10,000
	Store boat	1	450
	Camel dock	1	1,615
	Rowboats	12	200
	Calking flat	2	40
	General tools	....	100
	Office furniture	....	475

Money statement—July 1, 1890, to June 30, 1891.

General service:		
Available July 1, 1890	$42, 421. 45	
Allotment, act September 19, 1890	184, 000. 00	
Allotment, act March 3, 1891	70, 000. 00	
		$296, 421. 45
Expenses office Chief of Engineers	340. 00	
Transferred to reduction of observations	2, 500. 00	
		2, 840. 00
		293, 581. 45
Expenditures apportioned, first district	32, 047. 87	
Expenditures apportioned, preservation of works, first and second districts	3, 187. 47	
Expenditures apportioned, second district	1, 874. 81	
Expenditures apportioned, third district	1, 874. 81	
Expenditures apportioned, Greenville	21, 951. 61	
Expenditures apportioned, Ashbrook Bend	45, 649. 80	
		106, 586. 37
In Treasury	183, 638. 82	
In hand	3, 356. 26	
		186, 995. 08
Reduction of observations:		
Transferred from general service		2, 500. 00
Expended		2, 500. 00
Mississippi River Commission:		
Allotment, act September 19, 1890		75, 000. 00
Expended		18, 270. 23
In Treasury	52, 500. 00	
In hand	4, 229. 77	
		56, 729. 77
Surveys, gauges, and observations:		
Allotment, act September 19, 1890		150, 000, 00
Expended		31, 818. 13
In Treasury	110, 000. 00	
In hand	8, 181. 87	
		118, 181. 87
Illinois River to Ohio River, protection of the easterly bank of the Mississippi, near Cairo:*		
Available July 1, 1890		8, 600. 00
First district, Plum Point Reach:		
Available July 1, 1890	12, 165. 22	
Allotment, act September 19, 1890	297, 500. 00	
Allotment, act March 3, 1891	450, 000. 00	
Applied by general service	32, 047. 87	
		791, 713. 09
Withdrawn for reallotment	125, 000. 00	
Transferred to Memphis Harbor	105, 000. 00	
		230, 000. 00
		561, 713. 0[illegible]
Expended		135, 687. [illegible]
In Treasury	417, 500. 00	
In hand	8, 525. 78	
		426, 025. 7[illegible]

* Includes only funds under act of July 5, 1884.

Hickman, Ky.:		
Available July 1, 1890	$48,647.76	
Expenses office Chief of Engineers	118.00	
		$48,529.76
Allotment, act September 19, 1890		500.00
		49,029.76
Expended		1,659.34
In Treasury	42,843.17	
In hand	4,527.25	
		47,370.42
Columbus, Ky.:		
Available July 1, 1890		13,016.16
Expended		13,016.16
New Madrid (survey):		
Allotment, act September 19, 1890		1,000.00
Gauges:		
Available July 1, 1890		931.50
Expended	368.00	
Transferred to surveys, gauges, and observations, first and second districts	563.50	
		931.50
Surveys, examinations, and inspections:		
Available July 1, 1890		1,841.45
Expended	632.97	
Transferred to surveys, gauges, and observations, first and second districts	1,208.48	
		1,841.45
Survey St. Francis Front:		
Transferred from protection of levees, second district		300.00
Expended	249.50	
Transferred to surveys, gauges, and observations, first and second districts	50.50	
		300.00
Care of plant, first and second districts:		
Available July 1, 1890		20,452.15
Expended	20,444.80	
Transferred to plant, first and second districts	7.35	
		20,452.15
Surveys, first and second districts:		
Available July 1, 1890		1,255.30
Expended	731.14	
Transferred to surveys, gauges, and observations, first and second districts	524.16	
		1,255.30
First and second districts (plant):		
Allotment, act September 19, 1890	130,500.00	
Transferrod from care of plant, first and second districts	7.35	
		130,507.35
Expended		35,396.29
In Treasury	105,500.00	
Overdrawn	10,398.94	
		95,101.06

Preservation of works:		
Allotment, act September 19, 1890	$15,000.00	
Transferred from levees, Plum Point Reach	75.97	
Transferred from protection of levees, second district.	5,604.45	
Applied by general service	3,187.47	
		$23,867.89
Expended		5,351.37
In Treasury	15,000.00	
In hand	3,516.52	
		18,516.52
Surveys, gauges, and observations:		
Allotment, act September 19, 1890	15,000.00	
Transferred from gauges, first district	563.50	
Transferred from gauges, second district	12.50	
Transferred from sur. and ex., first district	1,208.48	
Transferred from sur. and ex., second district	1,119.89	
Transferred from sur., first and second districts	524.16	
Transferred from sur., St. Francis Front	50.50	
		18,479.03
Expended		5,314.94
In Treasury	14,500.00	
Overdrawn	1,335.91	
		13,164.09
Second district—Memphis Reach:		
Available July 1, 1890	16,178.67	
Applied by general service	1,874.81	
		18,053.48
Expended	5,437.95	
Transferred to Memphis Harbor	12,615.53	
		18,053.48
Memphis Harbor:		
Available July 1, 1890	5,619.74	
Transferred from Memphis Reach	12,615.53	
Transferred from Plum Point Reach	105,000.00	
		123,235.27
Expended		15,320.84
In Treasury	105,000.00	
In hand	2,914.43	
		107,914.43
Helena:		
Available July 1, 1890	2.80	
Allotment, act September 19, 1890	22,500.00	
		22,502.80
In Treasury	22,500.00	
In hand	2.80	
		22,502.80
Gauges:		
Available July 1, 1890		282.50
Expended	270.00	
Transferred to surveys, gauges, and observations, first and second districts	12.50	
		282.50
Observations and discharges:		
Available July 1, 1890		2.07
Expended		2.07

Surveys, examinations, and inspections:		
Available July 1, 1890		$1,575.06
Expended		455.17
Transferred to surveys, gauges, and observations, first and second districts	$1,119.89	
		1,575.06
Third district—Lake Providence Reach:		
Available July 1, 1890	6,526.66	
Transferred from protection of levees, fourth district	9,000.00	
Applied by general service	1,874.81	
Allotment, act September 19, 1890	185,000.00	
Allotment, act March 3, 1891	330,000.00	
		532,401.47
Withdrawn for reallotment		125,000.00
		407,401.47
Expended		17,835.68
In Treasury	358,000.00	
In hand	31,565.79	
		389,565.79
Vicksburg Harbor:		
Available July 1, 1890	37,305.75	
Allotment, act September 19, 1890	85,500.00	
Transferred from Delta Point	156.58	
		122,962.33
Expended		38,497.93
In Treasury	70,500.00	
In hand	13,964.40	
		84,464.40
Vicksburg Harbor—Delta Point:		
Available July 1, 1890		156.58
Transferred to Vicksburg Harbor		156.58
Greenville, Miss.:		
Available July 1, 1890	3,482.48	
Allotment, act September 19, 1890	100,000.00	
Allotment, act March 3, 1891	100,000.00	
Applied by general service	21,951.61	
Temporarily transferred from Lake Bolivar Front	2,713.74	
		228,147.83
Expended		30,647.83
In Treasury	197,500.00	
In hand	0.00	
		197,500.00
Ashbrook Neck:		
Allotment, act September 19, 1890	300,000.00	
Applied by general service	45,649.80	
		345,649.80
Expended		130,687.95
In Treasury	210,000.00	
In hand	4,961.85	
		214,961.85
Plant:		
Allotment, act September 19, 1890	100,000.00	
Allotment, act March 3, 1891	30,000.00	
		130,000.00
Expended		51,466.70
In Treasury	75,000.00	
In hand	3,533.30	
		78,533.30

Lake Bolivar Front:		
Available July 1, 1890		$20,289.72
Temporarily transferred to Greenville	$2,713.74	
Expended	1,619.57	
In hand	4,333.31	
		15,956.41
Gauges:		
Available July 1, 1890		498.90
Expended	360.00	
Transferred to surveys, gauges, and observations	138.90	
		498.90
Surveys, examinations, and inspections:		
Available July 1, 1890		1,062.26
Expended		1,062.26
Surveys, gauges, and observations:		
Allotment, act September 19, 1890	12,000.00	
Transferred from gauges	138.90	
		12,138.90
Expended		6,741.81
In Treasury	4,000.00	
In hand	1,397.09	
		5,397.09
Dry dock:		
Allotment, act March 3, 1891		20,000.00
Fourth district—New Orleans Harbor:		
Available July 1, 1890	48,519.62	
Expenses office Chief of Engineers	112.00	
		48,407.62
Allotment, act September 19, 1890		100,000.00
		148,407.62
Expended		78,688.08
In Treasury	40,000.00	
In hand	29,719.54	
		69,719.54
Red and Atchafalaya rivers:		
Available July 1, 1890	23,731.63	
Allotment, act September 19, 1890	225,000.00	
		248,731.63
Expended		101,622.35
In Treasury	140,000.00	
In hand	7,109.28	
		147,109.28
Natchez and Vidalia:		
Available July 1, 1890		675.65
Expended		675.65
Natchez, Miss. (survey):		
Allotment, act September 19, 1890		1,500.00
Expended		1,385.31
In hand		114.69
Gauges:		
Available July 1, 1890		400.02
Expended	278.13	
Transferred to surveys, gauges and observations	121.89	
		400.0[illegible]

Surveys, examinations and inspections:		
Available July 1, 1890		$1,507.41
Expended		1,507.41
Surveys, gauges, and observations:		
Allotment, act September 19, 1890	$12,000.00	
Transferred from gauges	121.89	
		12,121.89
Expended		6,421.39
In Treasury	3,000.00	
In hand	2,700.50	
		5,700.50
Levees (first district):		
Plum Point:		
Available July 1, 1890		75.97
Transferred to preservation of works, first and second districts		75.97
Levees (second district):		
White River Basin:		
Available July 1, 1890	3,954.35	
Allotment, act September 19, 1890	192,500.00	
		196,454.35
Expended		77,588.20
In Treasury	100,000.00	
In hand	18,866.15	
		118,866.15
Upper Mississippi levee district:		
Available July 1, 1890	510.08	
Allotment, act September 19, 1890	90,000.00	
		90,510.08
Expended		55,543.92
In Treasury	15,000.00	
In hand	19,966.16	
		34,966.16
Yazoo Front:		
Allotment, act September 19, 1890		15,250.00
Expended		1,505.18
In Treasury	15,250.00	
Overdrawn	1,505.18	
		13,744.92
Protection of levees:		
Available July 1, 1890		5,904.45
Transferred to survey St. Francis Front	300.00	
Transferred to preservation of works, first and second districts	5,604.45	
		5,904.45
vees (third district):		
Lower Mississippi levee district:		
Allotment, act September 19, 1890	198,000.00	
Transferred to protection	9,900.00	
		188,100.00
Expended		123,866.09
In hand		64,233.91

Levees (third district)—Continued.

Tensas Basin, Arkansas:		
Allotment, act September 19, 1890	$190,000.00	
Transferred to protection	9,500.00	
		$180,500 00
Expended		49,576.08
In Treasury	76,000.00	
In hand	54,923.92	
		130,923.92
Tensas Basin, Louisiana:		
Allotment, act September 19, 1890	95,000.00	
Transferred to protection	4,750.00	
		90,250.00
Expended		66,875.59
In hand		23,374.41
Protection of levees:		
Available July 1, 1890	747.43	
Transferred from protection of levees, fourth district	1,000.00	
		1,747.43
Expended		1,747.43
Protection of levees, Lower Mississippi levee district:		
Transferred from levees	9,900.00	
Reallotted	32,750.00	
		42,650.00
Expended		17,139.92
In Treasury	12,750.00	
In hand	12,760.08	
		25,510.08
Protection of levees, Tensas Basin, Arkansas:		
Transferred from levees	9,500.00	
Reallotted	47,500.00	
		57,000.00
Expended		19,706.68
In Treasury	22,500.00	
In hand	14,793.32	
		37,293.32
Protection of levees, Tensas Basin, Louisiana:		
Transferred from levees	4,750.00	
Reallotted	34,062.00	
		38,812.00
Expended		23,278.23
In Treasury	14,062.00	
In hand	1,471.77	
		15,533.77

Levees (fourth district):

Tensas Front:		
Available July 1, 1890		29,117.42
Expended		29,117.42
Tensas Basin:		
Allotment, act September 19, 1890	210,000.00	
Reallotted	40,521.00	
		250,521.0
Expended		84,999.8
In Treasury	120,500.00	
In hand	45,021.18	
		165,521.1

Levees (fourth district)—Continued.		
Right bank below Red River:		
Allotment, act September 19, 1890	$130,500.00	
Reallotted	43,750.00	
		$174,250.00
Expended		109,668.60
In Treasury	46,750.00	
In hand	17,831.40	
		64,581.40
Left bank below Red River:		
Allotment, act September 19, 1890	94,500.00	
Reallotted	23,688.00	
		118,188.00
Expended		87,781.80
In Treasury	23,000.00	
In hand	7,406.20	
		30,406.20
Protection of levees:		
Available July 1, 1890		18,160.13
Transferred to Lake Providence Reach	9,000.00	
Transferred to protection of levees, third district	1,000.00	
		10,000.00
		8,160.13
Expended		8,160.13
Levees—total:		
Available July 1, 1890	58,469.83	
Allotments, act September 19, 1890	1,188,000.00	
Reallotted	250,021.00	
		1,496,490.83
Transferred to Lake Providence Reach	9,000.00	
Transferred to preservation works, first and second districts	5,680.42	
Transferred to surveys, gauges, and observations	50.50	
		14,730.92
Expended		1,481,759.91
		756,804.59
In Treasury	444,062.00	
In hand	280,893.32	
		724,955.32

Consolidated statement, March 3, 1881, to June 30, 1891.

Act of March 3, 1881		$1,000,000.00
Act of August 2, 1882		4,123,000.00
Act of January 19, 1884		1,000,000.00
Act of July 5, 1884, less $5,000 transferred to snag boat service		2,065,000.00
Act of August 5, 1886, less $5,942.60 for expenses office Chief of Engineers		1,994,057.40
Act of August 11, 1888, less $4,859 for expenses office Chief of Engineers		2,840,141.00
Act of September 19, 1890		3,200,000.00
Act of March 3, 1891		1,000,000,00
Total specific appropriations		17,222,198.40
Balances from former appropriations applied to works below Cairo, under act of August 2, 1882, less $123.42, reverted to Treasury	$272,504.96	
Same for works above Cairo, under act of July 5, 1884	22,632.53	
Total balances		295,137.49
Received from sales, loss of property, and deposits		675.88
Reallotted		21.00
Total available		17,518,032.77
Expended		14,461,952.78
Balance July 1, 1891		3,056,079.99

Detailed statement, March 3, 1881, to June 30, 1891.

Districts.	Balances.	Appropriations and allotments.	Applied by general service.	From sales, etc.	Total available.	Expended.	In Treasury.	In hand.	Total balances.
Des Moines Rapids to Illinois River	$12,663.38	$195,000.00		$145.14	$207,808.52	$207,808.52			
Illinois River to Ohio River	9,969.15	470,000.00		126.60	480,095.75	480,095.75			
Protection near Cairo		50,000.00		10.85	50,010.85	41,410.85		$8,600.00	$8,600.00
Total	9,969.15	520,000.00		137.45	530,106.60	521,506.60		8,600.00	8,600.00
Survey St. Francis Front		10,122.61			10,122.61	10,122.61			
New Madrid Reach		200,721.86	$9,640.05	2.83	210,364.74	210,364.74			
Plum Point Reach		3,252,821.18	317,496.82	106.70	3,570,424.70	3,144,398.92	$417,500.00	8,525.78	426,025.78
Hickman, Ky		85,843.17	3,288.83		89,132.00	41,761.58	42,843.17	4,527.25	47,370.42
Columbus, Ky		41,150.92	2,599.08		43,750.00	43,750.00			
New Madrid (survey)		1,000.00			1,000.00	0.00	1,000.00	0.00	1,000.00
Gauges		1,436.50			1,436.50	1,436.50			
Observations and discharges		3,000.00			3,000.00	3,000.00			
Surveys, examinations, and inspections		1,791.52			1,791.52	1,791.52			
Levees—Plum Point		155,924.03			155,924.03	155,924.03			
Total first district		3,753,811.79	333,024.78	109.53	4,086,946.10	3,612,549.90	461,843.17	13,053.03	474,396.20
Survey St. Francis Front		4,000.00			4,000.00	4,000.00			
Helena Reach		8,000.00			8,000.00	8,000.00			
Levees—Long Lake		15,000.00			15,000.00	15,000.00			
Yazoo Front		156,200.00			156,200.00	142,455.18	15,250.00		*13,744.82
White River Basin		267,500.00			267,500.00	148,633.85	100,000.00	18,866.15	118,866.15
Upper Mississippi Levee district		140,000.00			140,000.00	105,033.84	15,000.00	19,966.16	34,966.16
Yazoo-Mississippi Delta		100,000.00			100,000.00	100,000.00			
Protection of levees		1,595.55			1,595.55	1,595.55			
Memphis Harbor		374,365.53		22.80	374,388.33	266,473.90	105,000.00	2,914.43	107,914.43
Reach		147,384.47	52,696.32		200,080.79	200,080.79			
Harbor and reach		431,792.38	138,232.94	27.14	570,052.46	570,052.46			
Helena		87,106.83	10,393.17		97,500.00	74,997.20	22,500.00	2.80	22,502.80
Gauges		987.50			987.50	987.50			
Observations and discharges		3,000.00			3,000.00	3,000.00			
Surveys, examinations, and inspections		1,880.11			1,880.11	1,880.11			
Total second district		1,738,812.37	201,322.43	49.94	1,940,184.74	1,642,190.38	257,750.00	41,749.54	*297,994.36
Care of plant, first and second districts		84,998.64			84,998.64	84,998.64			
Surveys, first and second districts		9,475.84			9,475.84	9,475.84			
Plant—first and second districts		130,507.35			130,507.35	35,406.29	105,500.00		†95,101.06
Preservation of works, first and second districts		20,680.42	3,187.47		23,867.89	5,351.37	15,000.00	3,516.52	18,516.52
Surveys, gauges, and observations		18,479.03			18,479.03	5,314.94	14,500.00		‡13,164.09

Survey Vicksburg Harbor		2,500.00			2,500.00	2,500.00			
unleveed Fronts		1,000.00			1,000.00	1,000.00			
Choctaw Reach		2,679.86			2,679.86	2,679.86			
Levees—Opossum Fork		120,000.00			120,000.00	120,000.00			
Yazoo Front		364,878.95			364,878.95	364,878.95			
Yazoo Front (Ben Lomond)		11,386.22			11,386.22	11,386.22			
Yazoo Front (Hughes Break)		6,849.69			6,849.69	6,849.69			
Tensas Front		566,723.00			566,723.00	566,723.00			
Tensas Basin, Arkansas		360,420.86		.08	360,420.94	229,497.02	76,000.00	54,923.92	130,923.92
Tensas Basin, Louisiana		90,250.00			90,250.00	66,875.59		23,374.41	23,374.41
Lower Mississippi levee district		246,564.82			246,564.82	182,330.41		64,233.91	64,233.91
Protection of levees		294,769.00		3.00	294,772.00	216,434.83	49,312.00	29,025.17	78,337.17
existing works		25,000.00			25,000.00	25,000.00			
Greenville, Miss		303,212.76	52,664.40		355,877.16	158,377.16	197,500.00	0.00	197,500.00
Repairs to floating plant		30,000.00			30,000.00	30,000.00			
Vicksburg Harbor—dredging and dam		369,968.70		25	369,968.95	285,504.55	70,500.00	13,964.40	84,464.40
Delta Point	25,770.13	107,579.88			133,350.01	133,350.01			
Lake Providence Reach		3,046,876.34	240,003.16	218.95	3,287,098.45	2,898,132.66	358,000.00	31,565.79	389,565.79
Care of plant and surveys		24,360.00			24,360.00	24,360.00			
Lake Bolivar Front		132,286.26	8,028.19	04	140,314.49	124,358.08		15,956.41	15,956.41
Ashbrook Neck		300,000.00	45,649.80		345,649.80	130,687.95	210,000.00	4,961.85	214,961.85
Plant		150,000.00			150,000.00	51,466.70	95,000.00	3,533.30	98,533.30
Gauges		1,461.10			1,461.10	1,461.10			
Observations and discharges		3,000.00			3,000.00	3,000.00			
Surveys, examinations, and inspections		10,149.46			10,149.46	10,149.46			
Surveys, gauges, and observations		12,138.90			12,138.90	6,741.81	4,000.00	1,397.09	5,397.09
Total third district	25,770.13	6,584,055.30	346,945.55	222.32	6,956,993.30	5,653,745.05	1,060,312.00	242,936.25	1,303,248.25
Survey Cubitt's Gap		137.14			137.14	137.14			
unleveed fronts		1,000.00			1,000.00	1,000.00			
Observations at Carrollton		3,000.00			3,000.00	3,000.00			
Bonnet Carré Crevasse		15,000.00			15,000.00	15,000.00			
Natchez and Vidalia Harbors	8,252.04				8,252.04	8,252.04			
New Orleans Harbor	147,670.39	381,183.86	1,527.61	04	530,381.90	460,662.36	40,000.00	29,719.54	69,719.54
Mouth of Red River	90,812.40	38,405.00			129,217.40	129,217.40			
Red and Atchafalaya rivers		662,500.00		20	662,500.20	515,390.92	140,000.00	7,109.28	147,109.28
Natchez, Miss. (survey)		1,500.00			1,500.00	1,385.31		114.69	114.69
Gauges		1,878.11			1,878.11	1,878.11			
Observations and discharges		9,000.00			9,000.00	9,000.00			
Surveys, gauges, and observations		12,121.89			12,121.89	6,421.39	3,000.00	2,700.50	5,700.50
Levees—Tensas Front		1,139,922.00		21.00	1,139,943.00	974,421.82	120,500.00	45,021.18	165,521.18
Atchafalaya Front		176,800.00			176,800.00	176,800.00			
Right bank below Red River		174,250.00			174,250.00	109,668.60	46,750.00	17,831.40	64,581.40
Left bank below Red River		118,188.00			118,188.00	87,781.80	23,000.00	7,406.20	30,406.20
Protection of levees—Tensas Front		23,000.00			23,000.00	23,000.00			
levees		104,000.00			104,000.00	104,000.00			
Surveys, examinations, and inspections		4,000.00			4,000.00	4,000.00			
Total fourth district	246,734.83	2,865,886.00	1,527.61	21.24	3,114,169.68	2,631,016.89	373,250.00	109,902.79	483,152.79

Detailed statement, March 3, 1881 to June 30, 1891—Continued.

Districts.	Balances.	Appropriations and allotments.	Applied by general service.	From sales, etc.	Total available.	Expended.	In Treasury.	In hand.	Total balances.
General service		$186,983.82		$11.26	$186,995.08	$0.00	$183,638.82	$3,356.26	$186,995.08
Reduction of observations		2,500.00			2,500.00	2,500.00			
Mississippi River Commission		75,000.00			75,000.00	18,270.23	52,500.00	4,229.77	56,729.77
Surveys, gauges, and observations		150,000.00			150,000.00	31,818.13	110,000.00	8,181.87	118,181.87
Grand total	$295,137.49	16,336,190.56	$886,007.84	396.88	17,518,032.77	14,461,952.78	2,683,793.99	435,526.03	§3,056,079.99

* Overdrawn $1,505.18
† Overdrawn 10,398.94
‡ Overdrawn 1,335.91

§ Overdrawn 13,240.03

APPENDIX C 1.

PAPER BY CAPTAIN CHARLES F. POWELL, CORPS OF ENGINEERS, ON A MEASUREMENT OF THE DEPRESSION OF THE FLOOD LINE, 1890, AT GAUGE STATIONS BELOW RED RIVER LANDING, FROM CONTIGUOUS CREVASSES.

The method of measurement used depends upon the relation between a gauge and the Red River Landing gauge, as derived from the gauge readings on the rising stage and between bank overflow and the stage when the first considerable crevasse occurred.

The gauge relations may be, and most probably are, different on rising and falling stages; also different for stages below bank and above bank; and the crevasses broke when the river was rising and above bank.

Red River Landing is the station farthest upstream which can be safely used for obtaining the gauge relations on account of the flood disturbances made by the Red and Atchafalaya rivers and the unleveed Tensas Front next above Red River. Below Red River Landing there were no tributaries nor new outlets during all the flood, except the crevasses whose net effect on the flood line is desired.

There may have been a crevasse effect at the standard gauge, and if so, the amounts of flood line depression, herein deduced, are too small.

Plate 1 shows the plottings on a large scale, being the points inclosed by circles, of the mean daily gauge readings.

The apparent irregularity or want of smoothness in resulting hydrographs is more noticeable in hydrographs plotted from the observed readings, 8 a. m. and 4 p. m. The irregularities may result from wind in raising or lowering the water surface temporarily, from tidal influence, errors of observation, or other cause.

Mean hydrographs, drawn through points inclosed by squares as shown on the plate, and representing the mean of five daily means, are plotted for neutralizing the irregularities named, and thereby for better defining the gauge relations.

The first and largest levee break, known as the Nita crevasse, occurred March 14, so no gauge reading after that date was used for the mean hydrographs.

From largest mean flood velocities in discharge observations at Red River Landing and Carrollton, it was found that the river flow for a day was about 100 miles; consequently the time intervals in half days, from Red River Landing to Bayou Sara, Baton Rouge, Plaquemine, College Point, and Carrollton are, respectively, 0.5, 0.5, 1.5, and 2 days.

The readings scaled from the Red River mean hydrograph and extending from February 1 to March 12, were divided into groups of four, whose means with the means of the respective corresponding scaled readings at each of the other stations were plotted as shown on plate 2, being the points there inclosed by circles. The curves through the respective sets of ten points are what may be termed curves of corresponding gauge readings.

It is needed to extend these curves to the abscissa, representing the highest gauge reading at Red River Landing, for scaling the ordinates, or to otherwise determine the ordinates, which would have been the highest readings at the other gauges had the gauge relations continued to the top of the flood as they obtained for the 40 days before the crevasses commenced to break. These deduced highest readings compared with the highest observed give a measure of the actual lowering of the flood line at each of the other gauge stations.

The 4-day means, described above, were divided into three groups; the curves drawn through the plottings of whose means, shown by inclosing triangles on Plate 2, are the mean curves of corresponding gauge readings, these curves not differing more than 0.1 of a foot from the first curves of corresponding readings.

All the latter named curves have the characteristic, so marked that it may be taken as a law of the curves, of being for arcs about equal on the vertical scale, alternately convex and concave towards the side of the origin of coördinates during a rise of bout a foot at Red River Landing; therefore, for such a rise, under the law the corsponding rise at either of the other gauges increases or decreases as the river goes p. Consequently, applying the maximum ratio of rise between the standard gauge ad another gauge for finding the rise at the latter, proportional to the remaining se (about 5 feet) at the former, would give too large a flood height, or in other rds a limit which the no-crevasse flood would not have reached.

The points of the curves of corresponding gauge readings between which the ras were taken as maxima are marked on Plate 2 by the intersections of short obne lines with the curves, and for the Carrollton curve are designated *a* and *b*. e vertical scale distance between *a* and *b* is 0.88 feet, and the horizontal 0.75 feet; highest observed reading at the Landing gauge above the reading of *b* is 5.23 t; then 0.88, 0.75, 5.23, the limiting flood height above *b* on the Carrollton scale.

The curve on Plate 2, marked max., is an extension of the Carrollton mean curve of corresponding gauge readings, made to pass through the point whose coördinates are the last two terms of the above proportion, referred to *b* as an origin.

An apparent law of the mean curves of corresponding gauge readings is their convexity toward the left, so decided that it merits acceptance. From the law it follows that true extensions of the curves will be to the right of tangents at the upper ends of the curves. The intersections of the tangents with the abscissa, representing the highest reading at Red River Landing, give readings on the other gauges, above which the no-crevasse flood would have reached.

In the absence of any reason that the gauge readings of that flood would have been nearer one limit, as found above, than the other, a mean of the limiting readings in each case is, from the data, the most probable height of the no-crevasse flood.

The following table gives the depressions of the flood line obtained by the foregoing method:

Locality.	Distance from Red River Landing.	Lower limit.	Higher limit.	Mean.	Date of highest observed gauge reading.
	Miles.	*Feet.*	*Feet.*	*Feet.*	
Bayou Sara	34.2	2.17	3.57	3.02	Apr. 21.
Baton Rouge	68.0	3.12	4.73	3.92	Apr. 21 and 22.
Plaquemine	88.2	5.19	6.78	5.98	Apr. 22.
Nita Crevasse	133.7				
College Point	137.7	4.16	4.79	4.48	March 16.
Carrollton	191.7	2.57	4.09	3.33	March 17.

The Nita crevasse was the only break below Red River in March, except three comparatively small breaks, one of which was closed April 10. The other principal breaks, with their dates and with volumes of discharge, measured three and four days afterwards, are listed below:

Dates.	Breaks.	Distance from Red River Landing.	Volumes of discharge per second.
		Miles.	*Feet.*
Apr. 22	Raccourci	14	18,468
23	New Morganza	22	117,792
22	Upper Morganza	23	40,950
21	Fanny Riche	31	40,320
22	Preston	37	10,000
30	Point Manior	43	12,000
23	Lobdell	60	57,300

Smaller and less important breaks occurred on and after April 21.

Since the first flow of a crevasse is small, and considering the dates of breaks and highest gauge readings in the tables, also considering the hydrographs, it follows that very nearly all of the lowerings of the flood line, as measured above, resulted from the Nita crevasse alone, and that the later crevasses did not affect the highest gauge readings at College Point and Carrollton. Such crevasses prevented the flood line, however, from going above its highest readings at Bayou Sara, Baton Rouge, and Plaquemine.

It is now proposed to give the amounts of the lowering of the flood line, based, not upon the gauge relations from observations of 1890 alone, as above, but upon the mean relations obtained from gauge readings of all the floods available and pertinent to the purpose. These floods and the periods of rising stage between bank overflow and the commencement of crevasses are, for Carrollton and Baton Rouge:

1890, Feb. 1–Mar. 11	At Red River Landing.
1888, Apr. 15–Apr. 30	
1887, Mar. 10–Apr. 8	
1884, Feb. 22–Mar. 12	

Plaquemine and College Point readings are missing for 1887 and 1888, and Bayou Sara readings for 1884, 1887, and 1888.

Proceeding as for 1890, Plate 3 shows the mean curves of corresponding gauge

readings from all the observations indicated. The following table gives the resulting amounts of the lowering of the 1890 flood line, also the mean amounts from 1890:

Locality.	Lower limit.	Higher limit.	Mean.	Remarks.	From 1890.
	Feet.	*Feet.*	*Feet.*		*Feet.*
Bayou Sara					3.02
Baton Rouge	1.83	2.60	2.22	From 4 years	3.92
Plaquemine	3.65	5.04	4.34	From 2 years	5.98
College Point	3.44	4.07	3.75	From 2 years	4.48
Carrollton	2.39	3.53	2.96	From 4 years	3.33

To get the maximum net effect of all the crevasses at one time, in depressing the no-crevasse flood, according to the data and method herein, there should be subtracted from the deduced flood heights, instead of the highest gauge readings, the readings at times obtained by applying time intervals from Red River Landing, April 23, a. m. The results would be larger than the amounts of the actual lowering of the flood line previously given by—

	Feet.
For Bayou Sara	1.1
For Baton Rouge	0.9
For Plaquemine	1.1
For College Point	2.6
For Carrollton	1.9

Such maximum net effect obtained April 23–25, and is the difference in height between what the no-crevasse flood would have been at that time and what the crevasse flood was.

CHAS. F. POWELL.

ST. LOUIS, *November, 1890.*

APPENDIX C 2.

PAPER BY CAPTAIN CHARLES F. POWELL, CORPS OF ENGINEERS, ON EFFECTS OF OUTLETS ON THE BED OF THE RIVER BELOW THEM.

ENGINEER OFFICE, UNITED STATES ARMY,
Sioux City, Iowa, May 3, 1891.

GENERAL: When secretary of the Mississippi River Commission, I instituted an investigation of the effects of outlets on the bed of the main river below them. The matter was explained to my successor, and a memorandum showing the intended scope of the investigation handed him; the data and plots, as far compiled or drawn, were left at the office. Since then I have added some data, and now, at your invitation, I send the following statement of the investigation and a discussion of results:

The first effort was to make copies of old hydrographic plots from engineer surveys and the delta survey, not on file at the Commission office; to examine the records and reports for obtaining all reliable and comparable measurements of the river sections near and below outlets, and to compile a history of the outlets where such measurements were obtained, for an intelligent discussion of the outlet effects. Requisite data are unfortunately limited, and for some of the outlets entirely lacking.

The measurements of the river sections below outlets were made at different heights and conditions of river stage. Judging that the effects of stage might mask the outlet effects, and, if known, furnish a key to the mystery of discrepant results, an examination was made of the effects of river stage at the discharge sections from Cairo to Carrollton, removed from outlet influence. This examination showed by means of plots, and in a decided way, that at the discharge sections named a generally rising river scours the bed and a generally falling river fills it; nothing came of attempts to trace the effects of comparatively small changes of stage, but the large net changes, considered as units, certainly appeared from the plots, showing hydrographs and areas of sections for graphic comparison, to cause effects on the bed as stated.

Laws of scour and fill at the discharge sections, which are in the straighter and narrower reaches of the river, may not obtain at wide and shoal places; a close examination of this point was intended, but is not now practicable. A discussion of it is not now specially pertinent to the present inquiry, since the four outlets con-

sidered are at deep reaches; only one, Morganza, is in a sharp bend; the others are in reaches more or less straight.

That the rising Mississippi with increased velocity and volume, and hence greater energy, should scour, and that the receding flood when the velocity is diminishing should deposit from its heavy load of sediment, is an equally good theory to the generally accepted one of fill below an open outlet and of scour below a closed one. It seems to me, while floods cause deposits that they are made on the receding stage and to its lowest point, and not on the advancing stage, and that the cutting out of bar channels across shoal places at low and falling stages should not be considered a proper exception to the general law indicated; neither should the case where the shifting of the thalweg on a rising river acts to temporarily mold a new form of section. In the first case a contraction is effected in a greater proportion than the diminution of volume; the channel, too, being better defined, is more closely followed by steamers, and a stirring up of the bottom deepens the channel in some degree.

Below Red River, where the outlets considered are located, the river width is about constant for all stages, the channel wide, and the bottom so deep that it can not be sensibly affected by steamer wheels. The river is more straight than above, and the thalweg location more constant. The tendency for the thalweg to take a shorter line when the river is rising is neutralized, more or less, in case of an outlet by the draw towards the outlet.

At the least, the record is such, omitting opinion or theory, that for a safe comparison of river sections to discover outlet effects, it should be made between sections measured under similar circumstances of river stage and condition.

Another side examination was to see about the effect of crevasses on controlling depths in the reaches below. Levee breaks, as well as breaks through the natural banks, generally occur where the river is deep and where a fill would be no present detriment to navigation; raising of the crossings would be detrimental. For this examination the only data which seemed available were the surveys of 1882 below the Mississippi crevasses of that year, from Malone to Arkansas City. Assistant Engineer J. A. Ockerson, who has furnished valuable aid throughout for the investigation, made the examination referred to. His statement is appended. He finds from the data, that while the fills in the pools were decided, the crevasses had but little effect on the controlling depth of the crossings.

The somewhat decided average fills at sections below the crevasses named, as shown by the surveys of 1882, have been prominently cited as positively proving that outlets do raise the river bed. Now, there were only two surveys, giving one set of comparisons; the first survey was made during the rising stage of the great flood of 1882 and the other at low water after the flood receded. The sections are not comparable for the purpose desired, there being no way of eliminating effects of river stage and condition, or of even showing which component, stage or crevasse, was the larger in making the fill, supposing that both acted to that end.

Another deceptive conclusion as to outlet effects on the river bed has been drawn from comparisons of sections above and below outlets, wherein the lower sections were found to be smaller, and made to apply particularly to outlets making from bends. This method assumes that sections of a river reach are normally of equal areas. An examination was made of sections at the head and foot of several bends, removed from crevasses; in a majority of cases the larger section was at the head. The theory of fills below outlets is derived from the fact of the lowering of the water surface at the outlet, and consequently the loss of slope and velocity below. A gain of slope and velocity above must be likewise acknowledged; a scouring effect results thereby, and the comparison of sections above and below does not show how much of the difference is due to scour at one section or fill at the other.

Therefore, to give a proper measure of outlet effects, sections below the outlet only should be compared together.

With this preface, longer than I wish it were, I proceed to the germ of the paper, commencing with the

MORGANZA CREVASSE.

History.—May 19, 1850, opened. After 1865, closed; no further record. April, 1866, closed; no record of next previous break. April 15, 1874, opened. February, 1884, closed. March 14, 1884, opened. January, 1887, closed; just after survey of that year. April 22, 1890, opened.

Surveys—Soundings on eight sections below the crevasse, covering about 5 miles of river, were made under the Commission, in 1883, 1887, 1888, and 1889, giving the following

Means.

Survey.	Condition of crevasse.	Maximum depth.	Mean depth.	Area.	Notes.
		Feet.	*Feet.*	*Sq. ft.*	
February, 1883.	Open for 9 years....	92.2	44.5	111,523	Carrollton gauge, 5 to 12 feet, rising towards high from 1.8 feet, January 1.
January, 1887..	Open for 3 years....	74.3	38.2	92,869	Small rise December, 1886; same January; last rise from February 1.
January, 1888..	Closed for 1 year....	80.5	39.1	98,484	Small rise December, 1887; good rise end of January, towards highest.
October, 1889...	Closed for 3 years...	74.8	36.7	91,701	Low and falling.

No other measurements were found. These are are good and reliable, and more than ordinarily numerous at each survey.

From the table it is found that a closure of the crevasse for a year was followed by a scouring of the channel; a continual closure for 2 years more shows just about as much *fill* as the *scour* measures, so that an open crevasse and a closed one, each for 3 years, give nearly the same sized channel; the longest period of closure corresponds to the smallest of four channels, and the longest period of open crevasse corresponds to the largest channel; thus it would seem that the open crevasse scoured and the closed one filled the main river bed below.

Considering the stated law of river stage and condition alone we might expect the largest section in 1883, the next in 1888, the next in 1887, and the smallest in 1889, which is exactly what we find from the measurements.

Of the surveys, those of 1887 and 1888 only were made under approximately similar circumstances. The floods preceding were about of the same height, that of 1887 being a little higher near the outlet, and that of 1886 being generally higher for the whole river; the drop of the flood of 1886 was the more regular and sharp, possibly making a little more deposit than made in 1887 during the flood recession of that year; the spring rise of 1887 commenced earlier, and included more of the survey period than did that of 1888, but the former rise was the more irregular during the survey period.

Considering the effects of the river stage, however, as equal at the two surveys and no other cause applied than the closure of the crevasse, there results, as an effect of the closure for a year, a scouring of the river bed of 5 per cent. of the area of former section, about a large enough margin for errors of observation, indicating that the closing of the crevasse had if any influence but a small one of scour on the river bed below.

On the whole, and from a consideration of all the measurements, the only conclusion which seems warranted by the record for Morganza is that the influence of river stage greatly predominates over the outlet effect, and masks the latter so closely that neither its amount nor direction can be stated.

BONNET CARRÉ CREVASSE.

History.—December 19, 1849, opened; over 7,000 feet wide; 1850, closed after July; April 20, 1859, opened; 1859, closed; April 19, 1871, opened; winter of 1871 and 1872, closed; April 11, 1874, opened; 1882, closed after survey of same year.

Surveys.—The following gives dimensions of a section below the crevasse, taken from different surveys and reduced to a stage, reading 15.2 feet on the Carrollton gauge:

Surveys.	Condition of crevasse.	Depth. Maximum.	Depth. Mean.	Area.
		Feet.	*Feet.*	*Sq. ft.*
July, 1850,* Forshey	Open, one-half year.	66	46	147,500
February, 1851, Ellet	Closed, one-half year.	....	45	154,000
June, 1851, Smith	Closed, one-half year.	....	49	167,000
February, 1859, Pattison	Closed, 8½ years.....	80	44	151,200
September, 1874, Board of Engineers, La	Open, one-half year.	75	42	144,200
September, 1875, Board of Engineers, La	Open, 1½ years......	87	50	170,778
January, 1876,† Coast Survey	Open, 2 years......	82	55	188,302
October, 1876, Coast Survey	Open, 2½ years......	82	....	....
May, 1878, Board of Engineers, La	Open, 4 years......	78	43	147,359
March, 1879, Coast Survey	Open, 5 years......	76	....	....
February, 1880, Board of Engineers, La	Open, 6 years......	85	47	159,288
December, 1882, Mississippi River Commission	Open, 8½ years......	68	35	125,798
November, 1883, Mississippi River Commission	Closed, 1 year......	....	44	131,318
October, 1884, Mississippi River Commission	Closed, 2 years......	....	38	146,118

* Bottom velocity is stated (H. & A.) to have been more than 1 foot per second greater below the break than above.
† Stage some doubtful, but believed to be correctly used.

An inspection of the table readily shows the lack of fair correspondence between channel size and either condition of the crevasse. The direction of change of area is somewhat more often in favor of an increase of area for a closed crevasse and decrease for an open one than otherwise; the mean area when the crevasse is closed is 149,927, and when open 154,461 square feet.

The area of the section of 1859, after the crevasse had been closed 8 to 9 years, nearly equals the mean area of all sections; five sections from 1875 to 1882, when the crevasse was open, include the largest two, the smallest and two intermediate sized sections.

Arranging the areas in order of the greatest to the least, there follows:

No.	Area.	Crevasse.	Time of survey.	Notes.
	Sq. ft.			
1	188,302?	Open, 2 years	January, 1876	5 to 10 feet, rising.
2	170,778	Open, 1½ years	September, 1875	10½ to 6 feet, falling; sharp rise August and early September.
3	167,000	Closed. one-half year.	June, 1851	Highest late March; then slow fall; sharp rise from May 25 through June.
4	159,288	Open, 6 years.	February, 1880	11.5, 8.7, and 11.5 feet; generally rising in January.
5	154,000	Closed, one-half year.	February, 1851	
6	151,200	Closed, 8½ years	February, 1859	
7	147,500	Open, one-half year.	July, 1850	
8	147,359	Open, 4 years	May, 1878	10½ feet, falling slowly; highest March and May, 11.3 and 11.2 feet.
9	146,118	Closed, 2 years	October, 1884	1.8 to 3.9 feet; rising.
10	144,204	Open, one-half year.	September, 1874	1 to 2 feet; stand.
11	131,318	Closed, 1 year	November, 1883	1.8 to 5.3 feet; on winter rise.
12	125,798	Open, 8½ years	December, 1882	2.5 to 1.8 feet; falling.

It can be noticed from the table that four of the first six areas are from soundings made during the rising flood months, January and February; that, contrary to the usual rule, there was a sharp late summer rise in 1875, possibly accounting by resulting scour for the large section of that year: and that a similar rise occurred in 1851 just before and during the survey; also, that the last six areas were measured in ordinary falling or low stage months, the notes showing that such stages obtained for five of the six surveys; in November, 1883, the time of the other survey, there was quite a sharp rise.

The last three surveys named in the first table, ones by the Commission, include soundings on nineteen sections below the crevasse, commencing at its lower end. Mean measurements of these sections are shown below. They are reduced to a datum different from the datum of the previous tables; these mean sections are judged to be good and more useful than the others, since the latter are single sections:

Means.

Date.	Crevasse.	Depth.	Area.	Carrollton gauge.
		Feet.	*Sq. ft.*	
December, 1882	Open 8½ years	61	153,671	2.5 to 1.8 feet; falling.
November, 1883	Closed 1 year	64	157,014	1.8 to 5.3 feet; rising.
October, 1884	Closed 2 years	68	173,055	1.8 to 3.9 feet; rising.

The increase of mean sectional area from 1882 to 1884, about 13 per cent., apparently indicates a scouring from a closed crevasse over that of an open one, which inference is confirmed by the measurement of the intermediate year.

The floods preceding the surveys were great ones; they reached the respective highest readings at the Carrollton gauge of 15.0, 15.4, and 15.6 feet; the highest points at the other stations differ in order from this; and the orders at the other stations also differ among themselves.

It might be noted that the levees of the lower river were extended and raised during the period of surveys, and that during the survey of 1882 the river was falling and in the other years rising. The latter two circumstances especially make the sections less comparable than they ought to be for a decided conclusion as to the crevasse effect; these alone might readily account for the changes of sectional areas.

On the whole, and considering all the observations, a conclusion for Bonnet Carré, similar to that drawn for Morganza, although less in degree, seems proper.

CUBITT'S GAP.

History.—Cubitt's Gap formed in 1862 from a cut through the bulkhead of fisherman's canal; the water flowed as through an orifice onto a flat of the Gulf, and soon commenced to form a delta, thereby causing the outlet to gradually deteriorate but not wholly closing. No record was found fixing the time of maximum flow or capacity of the gap.

Dimensions of the gap.

Survey.	Sectional opening.			Discharge per second.	Remarks.
	Width.	Max. depth.	Flood area.		
	Feet.	*Feet.*	*Sq. ft.*	*Cubic feet.*	
1868, Coast Survey	2,087				
May 1, 1875, Howell	2,850	115			Best depths 1 mile seaward, 4 feet.
June, 1875, Coast Survey	2,617	over 100	129,000		Discharge not over 109 per cent. of that of 1876.
Feb., 1876, Coast Survey	no chge.		119,000	124,660	Depth 1,200 feet seawards not over 10 feet.
May, 1877, Howell		113			
Dec., 1883, Heuer	2,875	66			

From the survey of 1876, it was found that the area of section 150 feet seawards from the opening was 83,300 square feet, and 1 mile farther the aggregate area of passes 58,748 square feet. From observations made by Major Davis in 1874, a depth of 124 feet was obtained at the entrance to the gap, and of 4 feet a few hundred feet seawards. Major Davis states that at that time there was considerable delta formation spread out fan-shaped with many outlets or passes quite shoal at the outer ends.

Professor Mitchell has remarked that the impinging of the river on the south point of the gap cut that part away faster than the north point shoaled; this explanation accounts for the widening at the head while the capacity of the gap may have been diminishing.

It is judged that the outlet attained its maximum capacity before 1874, and probably several years before.

SECTIONS OF MISSISSIPPI RIVER BELOW GAP.

2,500 feet below.

Surveys.	Max. depth.	Widths of water way.			Carrollton gauge.
		60 feet.	50 feet.	40 feet.	
	Feet.	*Feet.*	*Feet.*	*Feet.*	
1838, Talcott	75	1,300	2,100	2,850	
1864					Gap opened.
1866, Coast Survey	46			1,800	
May 1, 1875, Howell	54		1,080	2,200	Top of flood, 11.3 feet on May 3–18.
February, 1876, Coast Survey.	51			1,800	9.9 feet to 11.2 feet; spring rise.
March, 1882, Heuer	58		750	1,800	14 feet to 15 feet; top of great flood near end of March.
December 26, 1883, Heuer	48			1,540	Slow rise from Oct. 15 to Dec. 15; then 8 feet to 5 feet at end of December.

About two miles below.

Survey.	Max. depth.	Wipth of 40-foot water way.	
	Feet.	*Feet.*	
1838, Talcott	55	2,600	
1866, Coast Survey	49	2,000	
April or May, 1877, Coast Survey	43	900	Stage one-half to two-thirds, rising.
December, 1883, Heuer	42	800	Stage one-third to one-half, falling.

Planes of references for soundings.

1838, 1866, 1876, 1887	Supposed to be m. l. w.
1875	Low tide on low river at Head of Passes.
1882, 1883	Zero of United States engineer gauge at Head of Passes.

The tables show a very marked decrease of water way of the main river below the gap after it opened as compared with the single survey made several years before opening, for which no explanation is suggested other than the outlet influence. The smallest section observed, next below the gap, was in 1866, just about which year the outlet probably ran the fullest.

Cubitt's Gap appears from the observations to be a case where the fill on the river bed as an effect of the outlet considerably exceeded any opposing action of scour by rising stage of river.

That a fill below the gap did occur after 1866 is further shown by Marindin comparisons of mean depths of areas in the river as tabulated below. The surveys were by the Coast Survey. Further details are given in Mr. Marindin's report, for which see the Commission report for 1882:

Surveys.	Areas compared.	Mean shoaling.
		Feet.
1866–1876	From south point of gap for 1,300 feet downstream	1.6 or 0.16 per year.
1866–1877	From lower limit of above area to Cubitt's house	3.9 or 0.35 per year.
1866–1875	From Cubitt's house to very near Head of Passes	3.6 or 0.40 per year.

In connection with the investigation as to Cubitt's Gap, an examination was made by Mr. Ockerson of the Engineer surveys at the Head of the Passes. Mean depths in the part of the river covered by the surveys, about 2,000 feet long and next upstream from the South Pass works at the Head of the Passes, are shown below:

Time of survey.	Mean depth.	Carrollton gauge.
	Feet.	
June, 1880	26.7	10.1 to 6.4 feet; falling after highest in April.
1881	27.2	12.3 to 10 feet; falling after highest in April.
1882	27.4	Stand, 12.6 feet during June; highest in March and April; slow fall May 1 to June 1.
1883	28.2	13.7 to 12.5 feet, falling, highest in April.
May, 1884	27.0	Stand, 13.6 feet; highest in March; small fall April.
1885	26.0	11.7 to 10.8 feet, falling; highest January and February; irregular March and April.
(Mean)	27.1	
April, 1886	27.1	8.4 to 13.4 feet; rising towards last of May.
1887	28.0	14.2 to 8.9 feet; rising, then falling; highest in early May.
1888	27.0	10.3 to 14.1 feet; rising to highest in early May.
March, 1889	27.4	Rising, then falling; highest at middle of month.
1890	29.2	Rising 14.8 to 15.2 feet; highest in April, 15.5 feet.
(Mean)	27.7	

From this it does not appear that the shoaling next below Cubitt's Gap is duplicated since 1880 at the Head of the Passes. It may be noticed that the first six surveys were generally made during falling-stage months, and the last five generally during rising-stage months; also that the first two tables plainly indicate a relation between river stage and river bed in those cases where the stage is known.

THE ATCHAFALAYA.

History.—Before Shreve Cut-off, 1831, this stream was an outlet proper of the Mississippi; since the cut-off the Atchafalaya has remained practically an outlet, either by drawing off Red River water, which otherwise would have gone to the Mississippi, or by receiving water from the main river via Upper or Lower Old River, one or both. In the first case the Mississippi is depleted by the diversion of a tributary; in the other by the direct abstraction of part of its volume. In both cases

effects in the same direction, on the bed of the main river below Old River, although perhaps not of equal extent, might reasonably be expected.

The Atchafalaya was formerly choked and nearly filled for miles by immense rafts of timber; the removal of the rafts was undertaken in 1840 and the work steadily prosecuted until 1861. From reliable statements and observations it appears that upon removal of the rafts the Atchafalaya rapidly enlarged. The early commission reports and Major Benyaurd's reports about 1880 detail circumstances showing the enlargement and express opinions to the effect that the Atchafalaya had again become an important outlet of the Mississippi. In the former-named reports are given the following comparisons of a section at the head of the Atchafalaya:

Authority.	Year.	Section area.	High water, width.	Maximum depth.	Increase.	Per cent. of increase.
		Sq. ft.	*Feet.*	*Feet.*	*Feet.*	
Delta survey	1851	24,400	730	52	....	....
Delta survey	1859	28,700	830	63	4,300	.172
Major Howell	1874	39,160	891	114	14,160	.605
Major Benyaurd	1879	52,100	940	130	27,700	1.134

The following were compiled from discharge measurements:

Atchafalaya section 3,000 feet below Head.

[Datum 51 feet on Barbre Landing gauge, H. W. 1882.]

Date.	No. of observations.	Barbre Landing gauge.	General stage.	Mean area.	Mean maximum depth.
		Feet.		*Sq. ft.*	*Feet.*
June 16–July 23, 1880	2	28.7–30.0	Rising	41,901	86.3
Aug. 16–Oct. 5, 1880	3	15.9–10.4	Falling	40,281	82.7
Oct. 25, 1881	....	14.9	Rising	40,410	....
Dec. 13, 1881–Mar. 24, 1882	24	30.9–50.6	....do	40,653	87.6
Mar. 28–Nov. 16, 1882	56	50.9–13.3	Falling	39,654	89.1
June 29, 1883	1	38.7	....do	45,966	86.5
Jan. 31–Mar. 20, 1885	8	42.6–33.1	....do	44,020	93.6

Atchafalaya section at Simmsport.

[Datum 32.3 feet, Simmsport gauge.]

Date.	No. of observations.	Simmsport gauge.	General stage.	Mean area.	Mean maximum depth.
		Feet.		*Sq. ft.*	*Feet.*
Jan. 17–Mar. 12, 1889	13	20.4–32.3	Rising	43,212	79.8
Mar. 20–May 28, 1889	13	30.8–13.0	Falling	43,032	79.5
Mar. 6–Apr. 17, 1890	8	40.3–45.2	Rising	46,473	83.9
May 6–May 19, 1890	6	44.8–44.0	Falling	52,236	92.9

Some 16,000 square feet should be added to the Simmsport areas for comparison with those of the next upper section. Captain Kingman says in his report of 1889, that the extreme high-water area at site of dam No. 1 (Simmsport) was 63,470 square feet, and is expected to be 50,710 over the dam ; the dam was built in that year. It might be expected that the head of the river was larger than a few miles below, still it undoubtedly appears that the bed of the Atchafalaya enlarged very considerably from 1851.

Not only the river, however, but the whole basin should be considered as the outlet for high-water escape. The first record found of any leveeing at the head of the basin is an account of the United States levee from the Atchafalaya to Red River Landing; this was commenced in 1882 and completed in 1883. In late years the whole front had been closed to the river-bank levees, and probably the high-water capacity of the whole basin as an outlet of the Mississippi has in the last 4 to 2 years been restricted, or at least not enlarged.

For finding what times and extent the Atchafalaya was an outlet proper, the readings of Barbre's Landing gauge, since its establishment, June, 1880, were compared with those of the Red River Landing gauge after proper corrections, including slope from Old River to Red River Landing. In 1880 to 1890, except 1881, 1882, and 1887, the current was *up* Old River during the low-water months, the slope varying from 3.3 feet in 1889 to 7.3 feet in 1884. In the excepted years the current was *down* for the low-water months, the slope reaching maxima of 4 feet in 1880, 9 feet in 1882, and 12.5 feet in 1887. During high and medium stages the slope was generally from 0 to 1 and 2 feet, occasionally about 3 feet, and rarely 4 feet, and of very irregular and changeable direction. So we see that the Atchafalaya for the last 10 years has generally received Mississippi River water during the lower stages, and only in an intermittent way during other stages.

Mississippi River sections at Red River Landing (Delta survey).

Date	Area between banks at high water.	Maximum depth.	Remarks.
	Sq. ft.	*Feet.*	
March, 1851	270,208		Section 25, in front of post-office.
1851	260,784		Section 26.
High water 1858	240,000	126	Two sections.

NOTE.—The high waters of 1851 and 1858 at Natchez were the highest in June and April, the former 1.4 and the latter 0.7 feet less than the highest at the same station in 1882, which reading at Red River Landing gauge is the datum for the following sections, taken from the Commission discharge measurements:

Mississippi River sections at Red River Landing.

Date.	No. of observations.	Red River Landing gauge.	General stage.	Mean area.	Mean maximum depth.
		Feet.		*Sq. ft.*	*Feet.*
Dec. 14, 1881-Mar. 27, 1882	55	30.3-48.5	Rising	227,321	78
Mar. 28-Oct. 17, 1882	145	48.4- 9.2	Falling	255,169	81
Oct. 21-Nov. 23, 1882	22	10.5-mean	Low	246,519	79
Mar. 21, 1884	1	46.1	Rising	237,842	
Oct. 6-Dec. 16, 1884	54	11.9-mean	Low	251,453	84
Dec. 19, 1884-Feb. 4, 1885	28	8.8-42.1	Rising	256,090	87
Feb. 5-Mar. 30, 1885	35	42.1-35.4	Falling	257,152	96
Jan. 10-Mar. 13, 1889	35	19.5-34.0	Rising	235,034	85
Mar. 14-May 29, 1889	32	33.9-13.7	Falling	236-717	86
Feb. 21-Apr. 18, 1890	15	41.8-47.8	Rising	223,531	85
May 1-May 20, 1890	6	47.4-46.0	Falling	237,971	82

There is doubt of the relative locations of the two sets of sections. The Delta survey section may have been as much as a mile upstream from the Commission's. The record as far as obtained shows a shoaling, not extensive, of the main river at Red River Landing from the period of 1851–1858 to 1881–1890; it does not seem practicable to trace any sure correspondence between the amount or rate of shoaling and the growth or diminution of the basin outlet. The changes of sections in the last period of measurement are not explained by scour on a rising stage and deposit on a falling one; other causes had more effect in this case. Besides the want of definite data, the situation is complicated by the Red River element making the outlet an intermittent one, and changeable between overflow from, and inflow into, the Mississippi, especially for high river; Red River Bar appears from the map to have grown downstream, thereby forcing a motion of translation, in the same direction, to the normal section of the river. Raccourci Cut-off, 3 or 4 miles below Red River Landing, and completed in 1847, probably increased depths next above the cut-off for that time and a short period after.

While it may not be safe to base any general law on the effects of the Atchafalaya outlet, it can be said that the filling of the main river bed below, is not fully and satisfactorily referred to other cause.

This completes the record of all outlets where measurements exist of the river bed below the outlet and made before and after it formed.

Reviewing the conclusions above, it may be noticed for outlets at and below Red

River (from where they can be led directly to the Gulf), that, as far as the record goes, the large all-stage outlet was found to cause a measurable and remaining fill in the main river below, but not the smaller and high stage crevasse. When the latter ceases to flow the effect of the river, is by scour, to return to its normal section of bed; and the action of 10 per cent. to 20 per cent. of the whole river for about one-fourth of the time ought not to decidedly influence it for the whole time.

Very respectfully, your obedient servant,

CHAS F. POWELL,
Captain, Corps of Engineers.

Gen. C. B. COMSTOCK,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

STATEMENT BY ASSISTANT ENGINEER J. A. OCKERSON, ON THE EFFECT OF CREVASSES ON CONTROLLING DEPTH OF THE MISSISSIPPI RIVER.

The principal work bearing on this question is to be found in the surveys of December, 1881, and January, 1882, and the resurvey made below the crevasses in October, 1882.

The first-named survey was made prior to the great flood which caused the crevasses in 1882, and the resurvey was made several months after the flood had receded.

The latter survey was in the main confined to resounding the sections in the vicinity of and below the crevasses in four different reaches between Malones and Arkansas City.

* * * * * * *

In the first reach, from Malones to Australia, about 14 miles long, 23 sections were resounded. Five out of that number show an increase in maximum depth, and 18 show a decrease from 0.5 to 13.5 feet; or an average decrease in the thalweg depth of 3.7 feet for the entire reach.

The second reach extends 8 miles down from Riverton. There were 14 sections resounded, among which are 2 with greater depth and 12 with depths ranging from 9.2 to 34 feet less than the same sections before the crevasses occurred. This gives an average decrease in thalweg depth for the entire reach of 14.1 feet.

The third covers a distance of 9 miles from Bolivar down and 17 sections were resounded. Two of these sections are deeper and 15 show a shoaling of from 2.2 to 47.7 feet, or an average decrease in the thalweg depth of 14.4 feet for the whole reach.

The fourth reach covers a stretch of about 5 miles near Arkansas City and embraces 8 sections. Of these sections 1 shows an increase in depth of 1 foot and 7 show a decrease of from 0.8 to 36.9 feet, or an average decrease in thalweg depth of 18.2 feet.

It will be observed that the original survey of the reaches named were made during a rapidly rising and high stage of river, ranging from 22.6 feet below high water on the first reach to only 5 feet below high water on the fourth reach; and during the resurvey the stage was nearly uniform for all of the reaches, and about 36 feet below high water.

On the first reach, where the outflow through the crevasse was small, and where we find the least difference between the stages of the surveys, there is the least average decrease in depth; while on the fourth reach, where the difference in stages is largest, we find the greatest average decrease in depth.

On the second and third reaches, where the crevasse discharge is much larger than in either of the others, but the difference in stages much less than in the fourth reach, we have a large average decrease in depth.

With the exception of the first reach, where the channel is divided by Island 68, the greatest decrease in depth occurs in the deep sections of the bends, and the least in the shallower sections on the crossings. In fact the only sections that show an increase in depth in the last three reaches are on crossings. This might, in a measure, be accounted for by the fact that, during the falling stage, bars cut out more rapidly than the pools which separate them.

It may be well to mention, also, that it is impracticable to make the sections of the two surveys and the soundings on them identical, owing to the depth of water and the rapid current. The discrepancies arising from this cause would probably balance in a large number of observations, and should not seriously affect the results.

It would be better and more satisfactory if the surveys covered an entire cycle from one low stage to the next, as has been done at several of the discharge stations. In the sections compared the highest stage is below a general overflow stage.

In the comparisons made of these four reaches, the differences between the fills in the pools and on the crossings are so marked that the conclusion, as far as this data

goes, seems unavoidable, that the crevasses have had but little effect on the controlling depth of the crossings.

It may be urged that the first effect when the flood is receding is to sweep the crests of the bars into the pools, but this data gives no information on this point. It should be borne in mind, however, that several months elapsed after the flood began to recede before the resurvey was made.

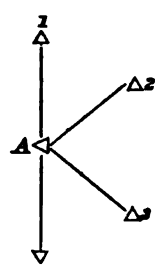
Appendix C 3.

INSTRCUTIONS FOR SECONDARY TRIANGULATION, PRECISE LEVEL, AND TOPOGRAPHICAL AND HYDROGRAPHICAL FIELD WORK.

INSTRUCTIONS FOR SECONDARY TRIANGULATION.

Locating stations.—In locating stations it is desirable to fix them at such points as give good conditioned triangles. The smallest angle in any triangle should never be less than 30 degrees, and but few of these should be permitted to enter into the system. The triangles should lie in such a way that pointings can be made from any station to the stations immediatly above and below on the same side of the river. That is, blind lines should always be avoided. Other things being equal stations should be set where they can be readily found and where they will not be disturbed.

Reading angles.—The angles will be read with T. & S. Theodolites, Nos. 1 and 2. The instruments will be mounted firmly and protected from sun and wind when in use. The value of the angle will be determined by eight combined results read as follows:



The instrument being at A, carefully leveled and in good adjustment. With the vertical circle to the right, or telescope direct, and lower motion fixed, point successively to △ 1, 2, 3, and 4, recording the reading of both micrometers for each pointing. This gives a positive result for each angle. Then point to △ 4, 3, 2, 1, and record readings as before. This gives a negative result for each angle. A mean of the two gives one combined result. The readings in a positive and negative direction will eliminate twist of station or instrument, provided the readings occupy but a short period of time during which the twist, if any, is uniform.

For the next combined result. The telescope will now be reversed, that is, revolved through, leaving the pivots in the same wyes and the whole will be revolved 180 degrees in azimuth. The vertical circle will then be on the left; the limb will be shifted 22½ degrees, and the stations will be read forward and back as before. The notes for this series will be headed circle left. Reversing the telescope will eliminate errors of collimation, small level errors, and inequality of pivots. Shifting the limb so as to read the angles at equal intervals around the circle will eliminate periodic errors and errors of graduation.

The same program is followed until all the results are obtained, the limb being shifted and the telescope reversed after each combined result.

The micrometers should be adjusted so the run will be nearly zero. This should, however, be tested at the beginning of each day's work, and entered in the notebook.

Closing triangles.—The error in closing a triangle should rarely reach and never exceed 6 seconds, and the average closure should be much below this. This will require great care in the centering of instruments and targets. A discrepancy of one-third of an inch will give an error of a second in a distance of 1 mile. A transpar-

ent cloth, phaseless target will be used, the size varying with the length of triangle sides.

Base lines.—Base lines will be measured at intervals of about 75 miles. This will be done with the 300-foot steel tape. The line should be carefully staked out, and its grade determined instrumentally. Supporting stakes will be driven at intervals of 30 feet. The stakes marking the extremities of each tape will be firmly set and free from any disturbing influence due to tension of tape or otherwise. On these stakes strips of zinc will be fastened and remain until the whole measurement is completed. The temperature of the tape will be determined by three thermometers placed near the ends and in the middle of the tape. They will be attached to suitable supports and placed with their bulbs near the tape when measurements are being taken. Observers must be careful to keep sufficiently far away so as not to affect the thermometers.

The tape will be suspended in hooks at intervals of 30 feet, and attached in such a way that it may swing freely and eliminate friction as far as practicable. The tension of the tape will be kept uniform while measuring by attaching a weight of 16 pounds. The extremity of each tape length will be marked on the zinc strip with a fine line and suitably numbered. The preservation of these strips furnishes a ready means of comparison of each tape-length at any future time.

The line should be measured two or more times, with a discrepancy when reduced of not more than 1 in 250,000. This can readily be done if measurements are made on cloudy days or at night.

Observations for azimuth.—The azimuth of each base line will be determined by observing, with a triangulation instrument, two closely circum-polar stars at elongation on two different nights.

The instrument and light should preferably be at the extremities of the base or a triangle side. The following order of observing will be used:

First.	Second.	Third.	Fourth.
Circle right. Point to light. Point to star and note time. Read level direct and reverse. Point to star and note time. Point to light.	Shift limb 45 degrees. Circle left. Point to light. Point to star and note time. Read level direct and reverse. Point to star and note time. Point to light.	Shift limb 45 degrees. Circle left. Point to light. Point to star and note time. Read level direct and reverse. Point to star and note time. Point to light.	Shift limb 45 degrees. Circle right. Point to light. Point to star and note time. Read level direct and reverse. Point to star and note time. Point to light.

On the second night repeat this programme, starting with a reading of limb 45 degrees greater than the last reading of previous evening.

It will probably be found most convenient in these observations to use Polaris, δ Ursæ Minoris, λ Ursæ Minoris and 51 Cephei.

The time will be determined by observing the meridian passage of high and low stars.

Stone line bench-marks.—At intervals of about 3 miles along the river, lines of pipe and tile marks will be set for future surveys.

These lines will be numbered and located about as shown on maps on file in this office.

The marks nearest the river will be far enough back to be safe from erosion for many years; the others will be half a mile further back.

In cases where the bluffs are near the river the rear marks may be omitted. The marks will preferably be placed at property corners, along public roads, or on property lines, in places where they can be readily found and where they will not be liable to disturbance.

It is desirable to determine the azimuth and distance between the successive marks on the same line when practicable. The marks should also be as nearly in a line as the conditions of location above named will admit.

The marks will be connected directly with the secondary triangulation, where practicable, by 3 pointings from 2 or more secondary stations, and an equal number from the point to be located to 2 stations that will give a fairly good triangle.

Where the points can not be located directly from the secondary work, a tertiary system may be used, starting and closing on a secondary line. In this work the angles may be read with a good 10-second transit, and the triangles should close within 15 seconds. A steel tape or chain may also be used, where desirable, in locating the point which is farthest from the river.

Cutting timber.—Cutting timber to clear the lines of sight or for material with which

to build stations should be avoided as far as practicable. Where cutting is necessary a strict account must be kept of the number of trees cut, their size, and kind of timber.

Descriptions of stations.—A minute description of each station will be made and entered in notebook kept for that purpose. This description will be complete for each station, and will show what the Geodetic point is and how marked. Its location with reference to surrounding objects will be shown by an accurate sketch giving azimuth and distance to bearing trees, houses, or other prominent objects.

A similar record will also be kept of the stone line marks.

INSTRUCTIONS FOR PRECISE LEVELS.

1. Before commencing operations the constants of the instruments will be determined. The most important of these is the value of one division of the level tube. This can best be determined by means of a level trier. It can also be determined in the field as follows:

Set up the instrument firmly, if possible, mounting it on a wooden post, or, better still, on a stone pier. Set up a rod in its tripod at such a distance that it can be distinctly read through the telescope. The distance should be at least 50 metres, or, if the air is very still, 100 metres, and should be carefully measured. Adjust the instrument carefully, taking such length of bubble in the level tube that its ends will be about the middle or tenth graduated line on each side. Direct the telescope to the rod, and by means of the elevation screw cause the bubble to run to near one end of the level. Carefully note the position of the three wires on the rod and the reading of the level. Now, by means of the elevation screw cause the bubble to run to near the other end of the tube, and note the reading of the wire and bubble as before. One result for value of 1 division of level can then be obtained. This operation should be repeated 10 times. The elevation of the rod should be changed occasionally between sets, in order to avoid estimating the same part of the same centimetre on the rod. It will be sufficient to run the bubble 5 divisions each side of its central position.

If

k = distance from instrument to rod,

d, d^1 = distance through which eye and object ends of bubble move when run from near eye end to near object end,

$\frac{d+d^1}{2}$ = amount of displacement of bubble between 2 readings.

r, r^1 = corresponding means of 3 thread readings on rod, and

v = value of 1 division of level in seconds of arc.

Then,

$$v = \frac{2\,(r^1 - r)}{k \sin 1''\,(d + d^1)}$$

2. With the value of 1 division of the level, tables will be constructed showing the correction to be applied to a rod-reading for an observed inclination of the level, and for a distance determined by interval between extreme threads.

If the level-bubble is well ground, equal displacements of the bubble, say of 2 divisions, will correspond to equal displacements on the rod.

3. Before using the level, or determining its value, the fastening of the tube in its case should be examined. One end should be clamped down just tight enough to prevent the tube from moving easily but not tight enough to strain the glass. The other end should be lightly clamped so that the tube may be free to expand and contract with temperature changes. The cotton packing at the ends should not exert a lateral strain on the tube. All level tubes will be numbered and have their numbers marked upon them.

4. In order to determine the inequality in the telescope rings, the instrument should be mounted on a stone pier or other firm support and carefully leveled. The level should be carefully adjusted and the instrument clamped to prevent its moving in azimuth. Now, with the eyepiece of the telescope over the elevating screw, note the reading of the bubble when level is set on telescope, both in direct and reversed position. Now reverse the telescope in the wyes, and read the level as before. Several sets of observatons should be made.

Let b, b^1 = inclination of telescope as denoted by means of level readings with telescope direct and reversed, then the inequality of rings $p = \frac{b - b^1}{4}$

Sixteen determinations of the value of p of two instruments in use on the lake survey gave probably errors of $\pm 0''.046$ and $\pm 0''.041$.

The inequality may be expressed in seconds of arc if desired, but for purposes of

computation is best expressed in terms of level divisions, as it can then be combined directly with the error of adjustment of level.

5. The centering of the object glass will be examined. This may be done as follows:

Draw out the eyepiece until the threads are no longer visible. Direct the telescope upon some well-defined object, and while looking at it rotate the telescope in its wyes. If the object remains steady, the object glass is sufficiently well centered. Should the object appear unsteady, the fault can only be remedied by a maker. The objective should be firmly screwed into the telescope.

6. The values of the wire intervals will be determined as follows: Set up a rod at carefully measured distances of 10, 20, 30, to 100 metres from the instrument. Read the rod ten times at each distance. The rod may be altered in elevation, the level may be caused to change, and the telescope may be rotated 180 degrees (inverted) in order to change the position of the threads on the rod.

Taking the mean of the ten observed differences of readings of the extreme threads at each station occupied by the rod, a table will be constructed giving in metres the distance of the rod from the instrument for any observed difference of reading between extreme wires.

7. Unless the rods used have been previously compared with some known standard, they will be compared with each other and their relative lengths determined. This may be done by establishing two fixed points, or two foot plates, at equal distances from the instrument and differing in elevation about 2.7 metres. The distance should be about 10 metres. Determine the difference of elevation of the points by reading each rod on each point. A comparison of the resulting differences of elevation will give relative lengths of metres on rods. Ten measurements with each rod will be determined. The elevation of the instrument will be slightly changed between each set in order to eliminate errors in estimating the millimetres. Each rod will be numbered and have its number marked on it. The rods should also be kept dry and provided with canvass covers to protect them while being carried to and from work.

The distance of the zero graduation above the steel spur on which the rod stands will be well determined. This may be done with a right angle triangle and rule. It may also be determined by means of another leveling rod, the graduations of which commence at the foot of the rod, by determining the height of the instrument above some fixed point and subtracting it from the reading of the rod to be determined. The relative lengths of the rods must be known.

Whenever a bench-mark is connected with in such a way that the rod is not placed directly on the bench-mark, this quantity *(a)* enters into the computation of difference of elevation.

8. Before commencing work at any time all adjustments will be carefully made.

(a) The telescope will be collimated by having a rod set up at a distance of 50 metres and noting the position of the wires on the rod when the telescope is normal and when inverted or rotated 180 degrees about its axis. The collimation error of the mean of the horizontal thread must not exceed 1.25 millimetres at a distance of 50 metres.

(b) The horizontality of the horizontal wires will be examined by moving the telescope in azimuth so that the rod shall appear to move through the field of the telescope. If the threads are horizontal the reading on the rod will be the same, the position of the level, which should be closely watched, remaining the same. If the threads are found to be not horizontal they will be made so by turning the telescope a small amount in the wyes. When the thread wires have once been made horizontal, small screws which abut against projection of wye above elevating screw should be so adjusted that when they press against this projection the wires are horizontal. If the vertical thread is then inclined, as shown by the plumb line attached to the rod, it must remain so.

(c) To make the axis of the level parallel to the upper surface of the rings, it is necessary to make the vertical planes passing through them parallel (lateral adjustment), and to make them equally inclined to the horizon (vertical adjustment).

To make the lateral adjustment, raise the clips fastening the level to the telescope, and revolve the level about the telescope a short distance each side of the vertical. If the bubble runs in opposite directions when on opposite sides of the vertical, the level is to be adjusted by means of the opposing horizontal screws at one end of the level until such is not the case.

To make the vertical adjustment, raise one of the clips and read the level in its direct position and also when it is reversed on the telescope. The difference between the differences of end readings in each position is four times the error of adjustment, and is to be corrected by the opposing vertical screws at one end of the level case. The error of adjustment must not be allowed to exceed two divisions of the level. Care must be taken that the telescope rings are free from dust while adjusting the level. After having made the vertical adjustment it will be necessary

to examine the lateral adjustment again, since making one of these adjustments affects the other.

(*d*) To make the level and vertical axis of revolution perpendicular to each other, loosen the small clamp screw at one end of the horizontal bar fastened to the vertical axis and by means of the elevating screw raise or lower that end of the upper horizontal bar until the telescope can be rotated 180 degrees from any position and have the level reading the same in both positions.

(*e*) To adjust the level attached to the rod, set up the rod in its tripod in such a position that when a plumb line is attached to the small hook near the top of the rod, the point of the plumb bob shall coincide with the point of a small cone attached to the rod near its foot. Now bring the level bubble to the center by means of the leveling screws. In making this adjustment the rod should not be exposed to the wind, as the plumb line is influenced thereby. This adjustment will be made at least once each day.

Each time that the instrument is placed on a station, its axis will first be made vertical by means of the leveling screws in such manner that the telescope may be turned around the horizon without the bubble of the level running a great number of divisions. The telescope is finally made horizontal by means of the elevating screw. The inclination at the moment of observing must not ordinarily exceed three divisions of the level, and never five divisions.

The instrument when in use ought always to be sheltered from the sun and wind. It is carried from station to station without being dismounted, but the level should be taken off and carried in the hand. The small clamp screw at the end of horizontal bar, and the large screw which fastens the instrument immovably to the tripod, should both be turned tight before moving the instrument.

The rods must be placed on the plates which accompany them and held in a vertical position as indicated by the spherical level attached. It is advisable to always use the same rod with the same foot plate. In placing the foot plates great care should be taken that they be horizontal, on firm ground, and not liable to change. The surface of the ground, if not firm or level, should be removed.

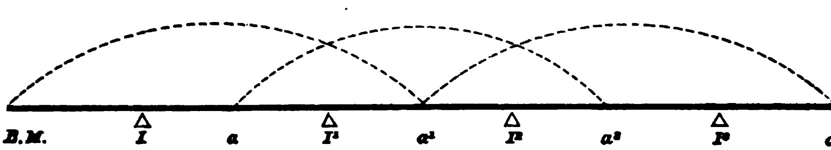
The errors of adjustment will be determined at beginning and end of each series of observations; that is to say, after having mounted the instrument and before dismounting it, and in all cases at least once each day. If the instrument has been deranged by a jar the corrections must be determined anew.

The error of collimation will be determined by two readings of the rod at a distance of 50 metres when the telescope is in its normal position and two when it is rotated 180 degrees in the wyes. The difference between the means of the two readings, after being corrected for the inclination of the level, must not exceed 2.5 millimetres at that distance, and commonly should not exceed 1 millimetre. The error of the adjustment of the level (inclination) will be determined by reading the level four times when direct and four times when reversed on the telescope, reversing it between each reading.

The error of adjustment must not exceed two level divisions, and commonly should not exceed one. All the details of the determination of the errors of adjustment must be entered in the note book in their proper place. It is always advisable to have the errors of adjustment as small as possible, and necessary that they be well determined. The time of making these determinations will be recorded in the note book.

In all work along the main line of levels each observer will duplicate his own work by running over the line in opposite directions, preferably under similar conditions as to illuminations, etc.

While connecting two bench-marks the order of using the rods will be as follows:



In the above figure let I I¹, I² —— etc., represent the successive stations occupied by the instrument. B. M. a, a³ —— etc., the positions occupied by Rod 1, and a, a² —— etc., the positions occupied by Rod 2. The instrument having been set up at I. Rod 1 is placed on B. M. and Rod 2 at a, making the distance I — a equal to I — B. M. Rod 1 is then read and immediately, afterward Rod 2. The time elapsing between these readings commonly will not exceed one minute and should not exceed 5 minutes. The instrument is then carried to I¹, and Rod 1 to a¹, the distances a — 1¹, and 1¹ — a¹, being equal. Rod 2 will then be read and immediately afterward Rod 1.

The instrument will then be taken to I' and the rods read in the order 1, 2. Work will be continued in this manner until the other bench mark is reached. Rod 1 must be placed upon this bench-mark, which will be the regular order if there have been an even number of instrument stations. If there have been an odd number of instrument stations, at the last station use Rod 1 for both backsight and foresight. While leveling the rate of progress in favorable weather will be about one kilometer per hour.

After having properly leveled the instrument at any station and having made the vertical thread coincide with the center line of the rod, the observation will be made and recorded in the following order: * First the level will be read, the tenths of the division being estimated; then the position of the threads on the rod will be read the millimetres being estimated; and finally the level will be read again. The observer will then read the rod a second time to make sure that no error has been made. The recorder will then take the differences between the readings of the middle and extreme wires to guard against errors, and if these differences denote any error the observations must be repeated. If an error exists it will be shown by too great a difference between the differences. This is a most important check and must not be neglected. These differences will also serve as a check upon the distances between the instrument and rods.

The recorder should also check the level readings to make sure that errors of whole divisions have not been made. This may be done by summing up the readings and noticing the length of the bubble. In reading the level by means of the mirror care should be taken that the position of the eye is such that there will be no parallax. Such positions can be determined once for all when the mirror is at its greatest angle of elevation, by a second person reading the level directly while the observer finds the position from which the reading of the level in the mirror is the same. The notes will be kept in the form given in note books. When once a number has been written down it must not be erased or made illegible. If wrong a line will be drawn through it and the correct number written above.

The lengths of sights taken will depend upon the condition of the atmosphere, but the rod should always be near enough to be seen distinctly. It will be seldom that lengths of sights greater than 150 metres can be taken. The back sight and fore sight corresponding to any instrument station must not differ in length by more than 10 metres, and the sum of the lengths of the backsights and foresights between any two bench-marks should be equal.

Whenever it is necessary that the line of levels should cross a river or other wide obstruction, a narrow place should be chosen. Firm points should be set upon the two banks; levels in good adjustment are set upon posts about 10 metres from each bench-mark, and both levels go through the same operation.

The error of adjustment is first accurately determined.—Call one of the levels A. A first reads on the bench-mark near it, once with the telescope normal and once with the telescope inverted, and then on the rod across the river five times with the telescope normal and five times with the telescope inverted. The error of adjustment of the level is again accurately determined. The rod across the river will need an extra vane. B performs the same operation simultaneously. A and B change places and repeat the observation at these new stations. The simultaneous levels eliminate refraction, the change of station eliminates curvature and small instrumental errors. Unless good results are obtained the levels should be repeated. If but one level can be used the operation will be performed in the same order, but the time occupied in crossing must be as small as possible. With a single Kern level this process has given for a river 815 metres wide five results, the mean of which has a probable error of $\pm$ $0^{mm}.5$. (Ohio River, Cairo, Ill.)

Permanent bench-marks will be established at intervals of 3 miles along the river and 5 miles on lines connecting the river line proper with the other levels or bench-marks.

These bench-marks will consist of a thoroughly verified tile 4 inches by 18 inches by 18 inches placed 3 feet below the surface of the ground and surmounted by a 4-inch wrought-iron pipe as a surface mark. The tile should have time to settle before leveling to it. Both tile and pipe will be suitably marked to designate the character of the point. In the center of the upper surface of the tile a copper bolt will be leaded, the upper surface of which will be the point of reference. These bench-marks will be placed where they can be easily found and where they will not be disturbed. Property corners should be utilized where practicable.

In addition to the above, benches should be established on permanent brick or stone structures by leading into them a horizontal copper bolt, with the letters U. S. P. B. M., and the number of the bench-mark cut near it. A small hole in the center of the bolt will be the point of reference.

In connecting with a bench mark if the bolt is vertical the foot of the rod is placed

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* It is preferable to keep the bubble in the center while threads are being read.

directly upon it. If the boat is horizontal in the wall of a building or other structure, it may be best connected in the following manner: Set up the instrument in such a position and at such an elevation that the small hole in the bolt may be bisected by the middle thread without displacing the level by more than five divisions, using the elevating screw for making this bisection. Since the instrument can be raised or lowered about two centimetres by means of the leveling screws, the instrument can be placed in such a position by two or three trials.

Now bisect the bench-mark with the telescope normal and also inverted, noting the reading of the level. Read the rod on the plate with the telescope in both positions. It is necessary to eliminate collimation by inverting the telescope, since the collimation of the middle wire is not the same as that of the three wires. The quantity of A (distance of zero above foot of rod) must be taken into account when a bench-mark is connected with in this manner. The distance of bench-mark from instrument must be determined and recorded.

Whenever work is stopped at least two temporary bench-marks should be established. These will consist of large nails or spikes driven their entire length vertically into the base of trees, or in the tops of sound stumps.

When not in the vicinity of trees or stumps, wooden posts may be firmly set in the ground with their tops flush with the surface and nails driven into them. When near the river, temporary bench-marks should be set every two kilometres. Every bench-mark will be fully described in a note book kept for that purpose. Its position with reference to the most prominent objects near it should be given by distance and direction. Public buildings, such as depots, court-houses, churches, etc., are the best positions for permanent bench-marks. In a village or town several permanent bench-marks should be established to secure some one against loss.

If a railroad is crossed the elevation of the foot of the rail will be determined, and if leveling along a railroad, the elevation of the foot of the rail at depots will be determined.

The elevation of the zeros of all water gauges and also the gauge bench-marks will be determined.

The datum planes of cities along the line of levels will be connected with and their elevations deduced.

Frequent connections will also be made with the United States Engineer bench-marks between St. Paul and Grafton.

In reducing the observations the nearest tenth of a millimetre will be retained. The distance will be taken out from the table to the nearest metre.

The limit of discrepancy in closing a polygon will be—

$$3^{\mathrm{mm}} \sqrt{\text{Distance in kilometres.}}$$

The distance referred to is the entire length of the polygon from bench-mark 1 to bench-mark 2 and back to bench-mark 1, and the limit of discrepancy refers to the polygons between successive bench-marks. If the discrepancy exceeds the prescribed limit then the entire polygon must be re-run one or more times, or until the difference of the means of the direct and reverse results is within the limit.

The notes will be kept in the following form.

BACK SIGHT.

[Left-hand page.]

Thread readings.	Mean.	Difference of threads.	Level.		Rod.	Remarks.
			Eye.	Object.		
7.95	....	207	....	....	....	
10.02	1001.7	206	11.1	11.1	12	
12.08	....	413	....	....	....	

FORE SIGHT.

[Right-hand page.]

Thread readings.	Means.	Difference of threads.	Level.		Rod.	Remarks.
			Eye.	Object.		
18.69	....	187	....	....	....	
20.56	2055.7	186	11.4	11.4	10	
22.42	....	373	....	....	....	

INSTRUCTIONS FOR TOPOGRAPHICAL AND HYDROGRAPHICAL FIELD WORK.

The objects of the survey of the Mississippi River are to obtain sufficient data for an accurate topographical and hydrographical map which may be used in studying the physical characteristics of the river, planning improvements, and also serve as a basis for future surveys, by means of which the changes in bed and banks may be ascertained and their causes and effects studied. The importance of having the work accurately done and the information embodied therein reliable is therefore apparent.

The experience derived in the surveys from Cairo to Donaldsonville, covering a period of several years, suggests the following instructions relating to the scope of the work and the methods to be employed. Other points will suggest themselves as the work progresses and new difficulties are met with.

General instructions.—A record will be kept showing the daily progress of the party. It will contain at the beginning the organization of the party, and the names and rates of pay of all persons connected with it. It will also give a detailed account of all occurrences of any importance which may in any way be of use in reducing the work or in settling accounts.

At the beginning of each day's work each note book in use will give locality of work, date, name of observer and recorder, number of instrument used, and corrections, if any, to readings of distance and azimuth.

In recording notes hard pencils will be used, and when an entry has once been made it should never be erased. Where an error has been made the record will be corrected by drawing a line through the first value and writing the new value above it. Corrections that are made after the work is done should be marked with the date of the change and the name of the person making the change.

All notes should be so full and plain that they could be readily reduced by one who has not seen the ground. This will require careful attention to details which may seem of trifling importance in the field.

All available information concerning the river and its adjacent banks which will aid in the proper representation of the characteristic features on the map or be valuable in the study of their changes will be fully noted.

Local names of bars, bends, streams, or other features will be carefully noted and the proper spelling of all names to appear on the map will be ascertained.

Permanent marks, as reference points for future surveys, will be established at intervals of about 3 miles along the river. There will be two on each side of the river nearly in a line, normal to the stream. The two nearest the river will be placed where they will be safe from the erosion of the banks for 20 years or more, and the others will be a half-mile further back. Where the bluffs are near the river the outer marks may be omitted. These marks should, when practicable, be placed near roads, property lines, or other places where they can be easily found at any time. The marks will consist of flat tiles bearing wrought iron pipes (see instructions for secondary triangulation), the tops of which should project not less than a foot above the ground.

Note books will be fully indexed at the end of each day's work. Each note book will be marked on the outside with a title giving locality of work, date, names of chief of party and observer. All note books will be entered on the office files and properly numbered as soon as parties return from the field.

The chief of party being responsible for the accuracy of the work done, should see that the work of each member of the party is properly checked and fully covers the ground required.

Tertiary triangulation.—Where the secondary stations are more than 3 miles apart a tertiary system will be carried giving points on either bank at intervals of a mile or less. This system will begin on a triangle side of the secondary system or a carefully measured base, and all of the available secondary stations will be used in the tertiary chain. The tertiary work will also close on a line of known length as a check on its accuracy. The discrepancy should not exceed 1 in 3,000. The system should be laid out and the angles read in advance of the topographers, so that the azimuths and lengths of sides can be used in checking stadia work.

The station point may be marked by a pole 2 inches in diameter stuck into the ground, and bearing a red and white flag to distinguish it from the ordinary sounding flags. A strip of white cloth wrapped near the bottom of the pole will admit of the pointings being made so low down that errors arising from disturbance of the pole by the wind will be inappreciable.

For observing, the instrument may be placed on an ordinary tripod centered over the hole after the pole has been removed.

The angles should be read with a 10-second instrument in good adjustment, and should be repeated at least three times on different parts of the line to check errors of reading.

It is desirable to have the first series read on azimuth. Having pointed to the

first station, read to all of the others in succession. Pointings should also be made to all of the sounding flags in the vicinity, as well as prominent objects on land, such as chimneys, houses, etc., the location of which will serve to check the topographical work.

For the second series slip the lower limb 60 degrees and read to the stations in the opposite order from the first series. Slip the limb the same amount again and read the third series.

The river ends of the stone lines will be made points in the tertiary system, and whenever practicable the stones should also be located trigonometrically.

Tertiary points which are likely to remain undisturbed for some time should be plainly marked with a strong stake 2 feet high, the number of the point, the initials of the observer and date being marked on it with red chalk.

Topography.—The detailed topography will cover a belt on each side of the river, which, in wooded country or on the bluffs, will be about one-half to three-fourths miles wide and in open country may reach about 1¼ miles. In this area there will be located, with transit and stadia, all points needed to plat accurately the important features on a scale of 1:10,000. In all work the scale of the plat should be borne in mind, so that only such points be instrumentally located as can be readily plotted.

Beyond the above limits outline surveys will be made defining streams, lakes, and the foot and main crests of bluffs with approximate elevations of same within a limit of 10 miles of the river. This work will be run with the transit or compass and stadia, and will frequently be connected with the detailed topography.

Within the limits of the detailed area there will be located the top and bottom of the river bank proper, the shore line of islands and bars, the banks and water lines of all waterways and lakes, with elevations of their water surfaces and depths, the points where the slope of the ground changes either in direction or inclination, the limits of rock ledges, the approximate limits and kinds of cultivation, and forests, roads, levees, fences, houses, etc., and in fact everything that may be necessary to a truthful representation of the section surveyed.

A sufficient number of elevations will be determined on the bottom lands to admit of putting in contours 5 feet apart. In a wooded area this will require cross sections at intervals of 500 metres or less. These should preferably be the continuation of lines sounded across the river. The space between the lines should also be examined and if any important features are found they should be located.

When the trees are too close together to admit of long sights it will be more expeditious and sufficiently accurate to use the compass needle for obtaining the direction, as it will then only be necessary to set up at alternate stakes.

The bluffs within the detailed area will be shown by contour lines 20 feet apart, the bluff curves being all some multiple of 10. The bluffs in the outline area may be shown by hachures.

Boundary lines, such as State, county, township, etc., coming within the limits of the survey, will be carefully located.

Section or township corners, where they are well identified, will also be connected with.

Great care must be taken in running out the stone lines. The azimuth of the lines must be accurately determined, and all distances will be carefully read, both forward and back. Each stone will be occupied instrumentally, and when practicable, the azimuth from one stone to the next will be read, and readings will be made to surrounding objects both as checks on the located positions of the stones and to aid in finding them in future time. A careful sketch and minute description will be given of each bench mark thus located.

All sounding flags, water gauges, and bench marks will be located.

In running the main transit line along the shore sufficient check shots will be made to known points on the opposite shore, to prove the accuracy of the positions given for the transit stakes. Such check shots should in fact be made use of in all parts of the work, so that errors of azimuth and distance may be detected and located. They also furnish means of correcting errors of position if any occur.

The error of level carried with the transit should never exceed one foot for the longest distances. In good work the discrepancies will rarely reach 0.5 feet. The work will be frequently checked by starting and closing on points whose elevations are known.

Distances and vertical angles between transit stakes will be read from each end of the line. On transit lines the distances between stakes, read with stadia, should never exceed 500 metres at a single reading unless they can be checked by intersections or other means. Single shots to distant objects may be read as far as the figures of the rod are distinguishable.

The transit stakes of each observer will be numbered consecutively in the same reach and each stake will be marked with its proper number and the initial of the observer so that it can be readily identified when connected with by others.

Careful sketches will be made in the field of the entire area surveyed and the located points will be indicated on the sketches and numbered to correspond with the pointings in the notes so there will be no difficulty in connecting the points properly on the field plats. The character of the immediate river bank will be frequently noted so as to show whether it is rock in place, loose rock, sand or silt, steep or sloping, caving or stable.

Checks on azimuth and elevation should be frequent and when obtained should be marked in the note book in such a way that the amount of error will be plainly shown and where the correction should be applied. Notes that are not full in this particular will always be open to suspicion which will throw doubt on the observer's honesty and the reliability of his work.

Discrepancies in closing on triangulation points should never exceed 0° 05′ in azimuth or 1 in 500 in distance. As a rule the discrepancies should be far within these limits.

The notes will be kept in the following form on the left-hand page of the note book, the other page being reserved for reductions, sketches and remarks.

[Left-hand page.]

[Vicinity of Phillips Landing, Nov. 3, 1882. Inst. Wurd, No. 154—Dis. Short 1 in 100, As. Cor. F. B. Maltby, observer. F. P. Gibbs, recorder.

Objects.	No. of pointing.	Ver. A.	Ver. B.	Distance.		Vertical angle.
				Read.	Corrected.	
		At △ 1. ° ′	° ′			′
△ Everett	1	95 10	275 10	100	101	+0.10
Top of bank	2	127 16	....	250	252	+0.8

[Right-hand page.]

Diff. of elev.	Elev.									
....	290.3									
+0.96	291.2									
+1.9	292.2									

Ordinary levels.—There will be a line of levels run along each bank of the river, the ordinary Y level being used for that purpose.

All turning points will be numbered so that the topographers can readily identify the points connected with.

The ordinary level lines will connect with all precise bench-marks in their vicinity.

The errors of closure should not in any case exceed 0.2 feet for the longest intervals. The two lines will check on each other at intervals of not more than 3 miles or in the vicinity of each stone line.

The elevations of stone-line bench-marks will be determined by duplicate lines of levels, the discrepancies between which should not exceed 0.05 feet. The adopted elevation will be the mean of the two determinations.

The elevations of all permanent stations near the river, except those on the bluffs, will be determined. Bench-marks will also be established on each bank at intervals of about a mile. These may be placed on buildings, trees, or other permanent objects near the river. A careful description, sketch of location, and corrected elevations of all bench-marks will be made and entered in a book kept for that purpose. These notes should be so full as to enable one not familiar with the ground to find the marks even after the lapse of several years' time.

All water gauges will be connected with by duplicate lines of levels from the nearest bench-marks and the elevations of their zero points entered in the gauge book. The elevation of the zero should be tested whenever there is a probability that the gauge has been disturbed.

The elevations of the water surface will be determined at the extremities of sounding lines at intervals of not more than 400 metres, and the time of the observation

will also be entered in the notebook. This, when corrected for change of stage, as shown by the local gauge readings, will give the slope, and also serve to check large errors in leveling.

Elevations of transit stakes, high-water marks, and surface of ground at sounding flags will be determined whenever it is practicable.

Level notes will be kept in the following form on the left-hand page of the notebook, the other page being reserved for sketches and remarks.

[R. B. near Grand Tower, December 12, 1884. Inst. B. & B. 140. M. Greenwood, observer.]

Stations.	B. S.	Ht. Inst.	F. S.	Elevation.
T. P. 113	4.206	340.527		336.321
⊙ 51			1.400	339.127
T. P. 114	4.031	341.399	3.159	337.368
△ 28			2.380	339.019

River crossings for connecting the two lines of levels will be made by the two observers taking ten simultaneous readings across the river in opposite directions. Then the observers and instruments should change places and repeat the observations.

The instruments should be in good adjustment, and when once focussed for the long distance should not be changed until the observations are completed. The mean of the values thus determined will be taken as the true value.

Hydrography.—A continuous record of the stage of the river will be derived from a suitable gauge read three times a day, its zero being referred to a known bench-mark as soon after it is set as practicable.

Sounding lines will be run normal to the stream at intervals of 250 metres, and the soundings on these lines will be as close together as practicable. These lines will be numbered consecutively.

A continuous longitudinal line passing through the deepest water on each section will be sounded.

On all crossings there will be sufficient soundings to determine the least channel depth between the pools.

As many soundings as practicable will be located by means of angles read simultaneously between located points on shore, with two sextants in the sounding boat. Intermediate soundings can be interpolated by taking them at equal intervals of time.

The character of the bottom will be frequently determined by means of a tallowed lead.

In water less than 10 feet deep it is convenient to use a pole divided to feet and tenths. A 10-pound lead is suitable in water from 10 to 40 feet deep. In greater depths it is desirable to use a lead weighing from 15 to 20 pounds.

A firmly twisted or braided hemp lead line three-eighths of an inch in diameter should be used. It should be marked with leather or cloth tags at intervals of one foot, the 10-foot marks being made conspicuous. The length of the lead line from the end of the lead to each 10-foot mark must be tested at the beginning and end of each day's work and the result entered in the note book. The lead line should be accurately marked, so as to avoid corrections as far as practicable.

The beginning of each line sounded will be headed in the notebook with the number of the section. A description of the character of the banks at intervals of about half a mile will also be entered in the notebook.

The elevation of the water surface at the time of sounding may be determined for each line by means of the levels as already described under the head of ordinary levels.

The notes will be kept in the following forms:

Sounding in the vicinity of St. Louis, November 15, 1889.

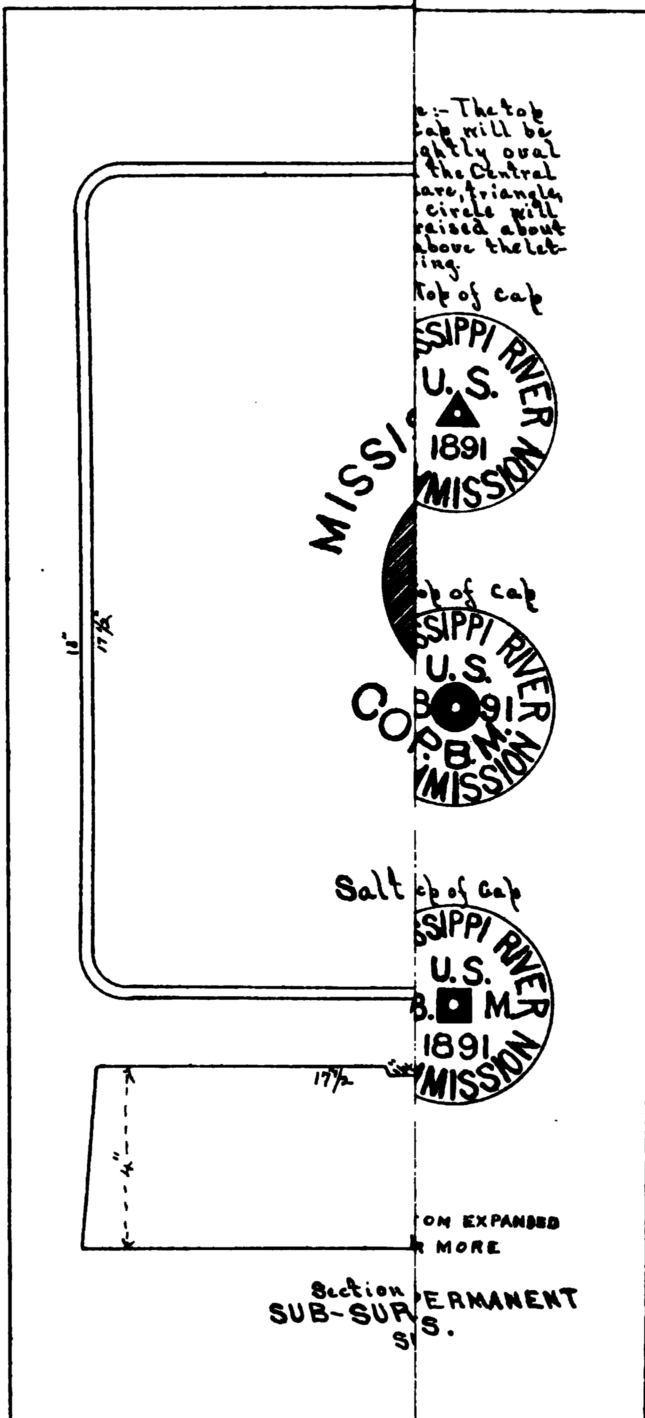
[E. L. Harmann, G. W. Wisner, observers; D. E. Perkins, recorder; J. Stott, leadsman.]

[Left-hand page.]

Time.	Observed depths.	Angles and ranges.	Character of bottom.

[Right-hand page.]

Correction. Lead line and stage.	Corrected depth.	Remarks.



Salt
MISSISSIPPI RIVER COMMISSION
U.S.
1891
B.M.
17½
4"
18"
ON EXPANDED
MORE
Section
SUB-SUR
ERMANENT
S.

Eng 91

The angles read to locate soundings will be numbered consecutively for each day's work, and the soundings located will be marked with corresponding numbers.

Computing and platting.—The coördinates of all tertiary stations and stone-line bench-marks will be computed and, together with the secondary stations, will form the basis for platting the topographical detail. The results of these computations will be kept in suitable form and preserved for future reference.

The work will be platted on a scale of 1:10,000. The field plats will be 26 by 30 inches in size, on which, near the center, will be printed a 12-inch circle divided to 15-minute spaces to facilitate the platting of polar coördinates.

Parallels and meridians, 1 minute apart, will be projected on the field plats and shown by fine red lines properly numbered. From these the △ stations will be platted. As this is the ground work for subsequent detail it should be carefully done and checked over to insure its accuracy. All △ stations, stadia stakes, and sounding flags and their elevations should be marked on the plats in red ink before the detailed work is put in.

All of the detail must be carefully platted and positions verified by check shots when such are available.

The contour lines and other outlines should preferably be put in by the observer who located them in the field.

Field plats will be laid out in such a way as to show both banks of the river with the adjacent topography on the same sheet whenever it is practicable. If the sheet is not large enough, plat the remaining work on a new sheet rather than enlarge by pasting pieces to the first sheet.

Banks that are too steep to admit of drawing in the contours, and abrupt banks of less than 5 feet in height, will be shown by hachures.

The elevations of water surfaces for each day's work will be plainly written on the plats.

All field plats must be completed in the field at least far enough to detect any instrumental errors in the field work before the platted area is out of reach. Hard pencils will be used in platting.

Each field plat will bear a legend giving locality and date, the names of the chief of the party, the observers and draftsman, the numbers and pages of the notebooks from which the notes were derived, and any other information that may be useful in the final reduction of the work. This data should be noted as the work is platted.

Care must be taken at the edges of the sheets to have the detail on successive plats join properly, and make sure that the ground is fully covered by the survey.

Nomenclature.—The word lake will be confined to the larger bodies of water, which are seldom if ever dry. They usually have a local name which should always be noted. Smaller and temporary bodies of water having no local names will be called ponds.

The word swamp will be applied only to ground which is covered with a growth of grass, cypress, elbow brush, willows, or such other vegetation as indicates that the area is generally wet, soft, or spongy.

The terms bayou, or creek, will be applied only to main water courses which connect lakes and swamps or other drainage areas with the river, and carry water to or from the latter, as the stage varies.

Minor swampy conduits will be called sloughs. This applies only to such as are not designated by local names.

The character of the material composing the bars and banks of the river will be frequently noted and carefully described.

The names of property owners or residents, of landings, wood-yards, fields, patches of timber, islands, chutes, bends, bars, points, and other local names necessary to a full description of the section surveyed will be fully noted and entered on the field plats. The following signs and abbreviations will be used: Secondary stations, ⊚; tertiary stations, △˙; transit stakes, ⊡; sounding flags, ⊙. Turning points in leveling notes will be written T. P.; bench-marks B. M.; temporary bench-marks T. B. M., and precise bench-marks P. B. M.

On the field plats the precise bench-marks, with their numbers and elevations, will be written thus: P. B. M. 27 ⊙ 218′.032; stone-line bench-marks thus: B. M. $\frac{10}{3}$ ⊡ 219′.23, in which the numerator is the number of the stone line, and the denominator the number of the stone on the line reckoned from the outer stone on the left bank.

The stone lines will be numbered consecutively upstream, beginning with number 1, near Cairo, Ill.

All elevations in the topographical work will be referred to the Memphis datum plane.

To reduce elevations from the Cairo datum to the Memphis datum subtract 13.13 feet from Cairo datum elevations.

The approximate mean Gulf level is 8.13 feet above the Memphis datum plane.

APPENDIX C 4.

REPORT OF MR. J. A. OCKERSON, ASSISTANT ENGINEER, ON PROFILE OF MISSISSIPPI RIVER, CAIRO TO DONALDSONVILLE.

OFFICE MISSISSIPPI RIVER COMMISSION,
June 18, 1891.

CAPTAIN: I have the honor to submit the following report on a profile of the Mississippi River, showing right bank and levees from Cairo to Donaldsonville; left bank and levees from Memphis to Vicksburg; mean high-water line 1872–1889; mean low-water line, 1872–1889; the high water of 1882 and of 1890; the low water of 1883; the lowest water during the period 1872–1890, and the mean high and the mean low water of 1881–1885.

The mid-bank line was taken as the initial line for distances. This mid-bank line was conceived to be a line lying midway between the high-water banks of the river. In cases where the river was divided by high islands the line followed the main channel, being midway between the high-water banks of the island and the main river bank.

In case of bars and low tow heads the line was considered to be midway between the banks proper and often lay entirely outside of the low-water stream.

The distances were laid off on this line with a pair of dividers taking 500 metre steps. For convenience in plotting, the stations were fixed at 1,000 metres, all the intermediate points being designated by the number of station plus the number of metres from the preceding station. All points were projected onto the mid-bank line and their distance from the origin there determined. It is therefore apparent that where there are sharp bends, a *short* distance on this line will sometimes represent a long stretch of concave bank, while a *long* distance on the same line will sometimes represent a very short distance of the convex bank. Therefore the profile does not show the local slope correctly, but is correct as a whole. Locally several miles of bank may be represented on the profile by a very short line and the slope will thereby be very much exaggerated, or a short length of bank may appear on the profile as very much longer, hence there will apparently be a long distance with little or no slope. This is especially true of levees which run across the narrow points instead of following around near the river.

In getting out the bank elevations, the field plots, showing all the elevations which had been determined by transit or level, were carefully studied. From these the highest continuous ground line within the limits of the surveys was determined, and such elevations along this line were tabulated as are necessary to show the slope or change of slope. It was not deemed essential to tabulate all of the elevations given on the field plots. This ground line was often a considerable distance from the river in consequence of battures or other low land along the river front. In the case of cut-offs, as Devils Elbow, Commerce, Walnut Bend, etc., the highest ground line lies along the old bends, where in some cases the elevations have not been well determined. Where the elevations *are* given, the points are projected on the mid-bank line, and a very long line of bank is represented on the profile by a comparatively short line. Several miles of the old bank may be projected into one point on the mid-bank line or the points may even overlap, hence the profile in such cases is largely a matter of judgment, as it cannot represent actual conditions.

In general, however, the ground profile represents the trace on a vertical plane of the highest continuous ground line within the limits of the survey.

It may be said that, except in cases of battures and cut-offs, this line lies near the river and often at its very edge. This is especially true below Red River, where the slope from the river back to the swamp is sometimes 15 feet or more per mile.

As the field plots show general conditions and features rather than minor details, there are of course a great many small ridges and depressions which are not shown and consequently not noted in the tabulation.

From my experience in topographic field work I am satisfied that more elevations are determined on the higher ground than in the depressions, as the rodman is much easier seen. Consequently there are a great many minor depressions which in the aggregate would permit the escape of a considerable amount of water which are not noted at all.

The ground line plotted from the data will therefore be somewhat too high.

The elevations of levee given refer to such levees as were in existence at the time the surveys were made and all other levees constructed up to February 1, 1890.

The locations of the levees constructed since the general surveys were made as well as the grade lines have been derived from the district officers and the levee engineers.

Below Warrenton the data as to levee grade line is not as full as it should be. The intervals between determined elevations are sometimes quite long and the profile of

the levee is shown as a straight line between such points. This part of the line may therefore be regarded as a close approximation only.

The elevations of high and low waters are such as have been determined under the direction of the Commission, and are comprised in tables of "high and low water," on file in this office.

The means for a period of years which are shown by points on the profiles were derived from the gauge readings at the several gauge stations, where a continuous record has been kept. There is no data for intermediate points.

The overflow on the left bank from Cairo to Memphis and Vicksburg to Baton Rouge being confined by the bluffs, which are generally near the river, may be considered as merely local, and the elevations of the immediate river bank have therefore not been tabulated.

Respectfully submitted.

J. A. OCKERSON,
U. S. Assistant Engineer.

Capt. CARL F. PALFREY,
Corps of Engineers, U. S. A.,
Secretary Mississippi River Commission.

APPENDIX C 5.

TABULATED RESULTS, WITH FIELD AND OFFICE REPORTS, OF DISCHARGE MEASUREMENTS ON THE MISSISSIPPI, OLD, AND ATCHAFALAYA RIVERS, 1887 TO 1889, INCLUSIVE, AND OF SOME EARLIER MEASUREMENTS NOT PREVIOUSLY PUBLISHED.

[When not otherwise stated, results are derived from final reduction at the office of the secretary Mississippi River Commission, 1889-'90.]

CONTENTS.

Results of discharge observations, Mississippi River, Old River, and Bayou des Glaises.

Date.	Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.					
			Water.	Below datum.	Mean.	Mean datum.	Maximum.						
HAYS LANDING, MISSISSIPPI, 1884.[1]													
	Feet.	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cu. feet.*		
Feb. 18	35.31	+ 0.50	159,481	....	56.8	....	84.0	2,810	....	7.496	1,195,493	....	Meter.
THROUGH WATERPROOF CUT-OFF, 1884.													
[The discharges through the old channel were observed about the same times, and computed to be 370,465 cubic feet per second in May, and 231,174 cubic feet per second in July.]													
May 25	[2]40.68	− 0.08	72,700	72,700	51.9	51.9	73.0	1,401	....	[3]6.455	469,300	....	Meter.
July 23	21.02	− 0.33	75,199	101,484	59.1	72.5	110.0	1,273	+28,784	[4]4.047	304,296	....	Double float.
OLD RIVER, ONE-FOURTH MILE ABOVE THE MOUTH, 1882.[5]													
Jan. 9	34.61	+0.45	23,461	24,794	26.4	26.9	35.7	890	....	3.257	76.400	VI—4	Double float.
11	35.10	+0.40	23,212	24.112	25.4	26.1	37.0	913	− 682	3.248	75.382	....	Do.
16	36.08	+0.15	22,389	22,389	24.3	24.3	38.7	923	− 1,723	2.592	58.031	XII—4	Do.
BAYOU DES GLAISES, HAMBURG, LOUISIANA, 1882.[6]													
Apr. 4	[7]49.30	− 0.10	5,920	....	18.5	....	....	320	....	2.233	13,220	VI—2	Meter.

ARKANSAS CITY, ARKANSAS, 1887.[8]

Mar. 22.......	46.59	+0.05	233,105	215,475	68.0	63.5	95.0	3,414	....	6.122	1,427,177	....	Meter.
23.......	46.60	+0.05	233,667	216,003	68.1	63.6	97.0	3,414	+ 528	6.197	1,447,969	....	Do.
24.......	46.61	0.00	247,404	229,701	72.1	67.7	97.0	3,416	+13,698	5 982	1,479,975	....	Do.
25.......	46.63	+0.05	240,852	....	70.1	....	....	3,420	....	5.839	1,406,809	....	Do.
26.......	46.63	0.00	234,299	216,518	68.2	63.8	96.0	3,420	—13,183	[9]6.079	[9]1,424,320	....	Do.
										[10]6.024	[10]1,411,896	....	Do.

[1] Results of other discharge observations at this station are published as follows: January 1 to November 25, 1882; gauge reading from 6.05 to 38.59 feet. Report Mississippi River Commission, 1883, page 222. Flood of 1882; gauge reading 34.14 to 38.58 feet. Report Mississippi River Commission, 1884, page 81. March 16, 1884; gauge reading 37.72 feet. Report Mississippi River Commission, 1884, page 116.

[2] St. Joseph gauge.

[3] The velocity observations were taken about 100 feet above the section sounded. Water surface was 87.326 feet above the Cairo datum plane.

[4] In computing the velocities the average departure of the floats, 46.5 feet, was assumed for each path.

[5] All these gauge readings were apparently on the Red River Landing gauge. In computing the velocities no corrections have been made for the departures of the floats from the normal to the discharge section, because these departures were small and in both directions. Results of other discharge observations at this station are published as follows: October, 1884, to March, 1885; gauge reading from 13.61 to 48.41 feet. Report Mississippi River Commission, 1887, page 2854.

[6] According to the daily log book and reports these observations were taken April 4, but the results given above were tabulated under April 5. As the field notes could not be obtained, no recomputation has been made.

[7] Barbre Landing gauge.

[8] The widths tabulated were scaled from the plotted cross sections and were measured from bank to bank. There was a discharge beyond the banks which increased the water width by 320 feet, and the water area by 1,084 square feet. This overflow amounted to 1,666 cubic feet per second the first two days, and subsequently to 1,626 cubic feet per second. The areas and discharges given above include these quantities. The datum plane was taken at 41.73 feet on the gauge, and datum width at 3,395 feet. As no soundings were taken March 25, the partial areas were found by interpolation. For the meter rating see page 11. Results of other discharge observations at this station are published as follows: October 6, 1884, to April 9, 1885; gauge reading from 7.42 to 41.73 feet. Report Mississippi River Commission, 1887, pages 2,838 to 2,840.

[9] A. M.

[10] P. M.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE, MISSISSIPPI RIVER COMMISSION, OF DISCHARGE OBSERVATIONS MADE ON THE MISSISSIPPI RIVER, AT ARKANSAS CITY, ARKANSAS, 1889.

OCTOBER 25, 1889.

The notes of these observations were received from the third district in May, 1889, for recomputation.

A map of the locality, drawn to a scale of 1:7200, accompanied the notes. This map shows the discharge section at apparently the same place as it was in 1884–'85, and also shows the arrangement of fixed signals on shore by which the sounding and velocity stations were located. The sounding stations were at intervals of 75 feet across the river, every fourth one being also a velocity station. The water's edge at each bank was located by measuring from the section hub on that bank; this also determined the river width for that day.

All the velocities of this series were measured with the W. G. Price current meter No. 5; for a description of the Price meter and outfit see Report Chief of Engineers, 1887, p. 2821. The chronograph slips did not accompany the notes; the registrations, however, had been counted in the field and recorded in the notes, and the results were adopted in this computation. The observer states that on February 22 and 23, no paper being on hand, the revolutions of the meter wheel were found by watching the registering points.

Three sets of rating observations were made with this meter at Arkansas City during the season. The results of reduction in this office by the usual method, are given in the following table:

Date of observations.	No. of observations.	a	b	Mean error of observations.	Mean error of a	Mean error of b	Remarks.
Dec. 4, 1888.........	12	3.7989	+0.1953	±0.280	±0.121	±0.215	In running water.
Feb. 27, 1889.........	15	3.9921	+0.0187	±0.188	±0.109	±0.165	Do.
March 27, 1889......	22	3.8421	+0.0785	±0.238	±0.075	±0.145	Do.

These results were combined by weighting a and b inversely as the squares of the mean errors of a and b in each series. The resulting equation, $y = 3.8712\,x + 0.0816$, was used in computing all of the 1889 series of discharges at this station.

(In 1884–'85 six sets of rating observations were made with this meter. The results are published in Report Chief of Engineers 1887, p. 2815. Also a set of rating observations was made with this meter near Wilson's Point, La., July 4, 1889. The results are published herewith.)

The computations of areas of cross section were made and checked in the manner described at length in Report Chief of Engineers, 1887, pp. 2823 to 2826. There were no lead-line corrections and the soundings were taken directly from the notebooks.

The discharges were found by the method described in the report accompanying the final reduction in secretary's office of the Carrollton observations of 1883. In the present series, however, the meter was usually run at six-tenths the depth from the surface, and for 150 seconds.

The datum areas were computed in the following manner: Datum was assumed at 41.73 feet on the gauge; this was the elevation of datum in 1884–'85, and was adopted in this work in order to conveniently make comparisons between the different series. Datum width was taken as 3,395 feet. The width at 35.25 feet on the gauge was taken, as observed, as 3,373 feet; at 29 feet as 3,363 feet, before February 15—after that date as 3,352 feet; at 22.67 feet as 3,321 feet. The following formulas were used in computing the datum areas in which h represents gauge reading, and w observed width.

Between 29 and 35.25 feet on the gauge:

$$\text{Datum area} = (41.73 - 35.25)\frac{3395 + 3373}{2} + (35.25 - h)\frac{3373 + w}{2} + \text{water area} = 21928$$
$$+ (35.25 - h)\frac{3373 + w}{2} + \text{water area.}$$

Between 22.67 and 29 feet on the gauge:

$$\text{Datum area} = 21928 + (35.25 - 29)\frac{3373 + {}^{*}3352}{2} + (29 - h)\frac{{}^{*}3352 + w}{2} + \text{water area} =$$
$$42944 + (29 - h)\frac{{}^{*}3352 + w}{2} + \text{water area.}$$

Below 22.67 on the gauge:

$$\text{Datum area} = 42944 + (29 - 22.67)\frac{{}^{*}3352 + 3321}{2} + (22.67 - h) \times \frac{3321 + w}{2} + \text{water area} = 64064 + (22.67 - h)\frac{3321 + w}{2} + \text{water area.}$$

The gauge used was the standard gauge at the elevator. The gauge inspectors' level notes of September 7, 1887, and October 4, 1889, show that this gauge was 0.2 feet too high, and all the records between those dates have been corrected by adding 0.2 feet to each reading. The zero of this gauge is 116.44 feet above the Cairo datum plane, survey Mississippi River.

The gauge readings given for days on which the discharge section was sounded correspond to mean time of observations; for other days the mean daily reading is given. The rise or fall in preceding 24 hours is derived from the regular record.

The maximum depths have been taken directly from the soundings.

The direction and force of wind have been copied from the notes; the direction is indicated by the figures of a clock dial, XII o'clock being upstream and denoting a downstream wind, VI denoting an upstream wind, etc.

The figures following the direction evidently indicate the velocity in miles per hour, as they agree with Trautwine's wind table, which had been copied into one of the notebooks.

The mean velocities, mean depths, mean datum depths, and scour and fill, have been computed in the usual manner.

Accompanying the tables are two plates; on one is the map of the locality, and on the other the discharges, areas, and mean velocities as abscissas, have been plotted to gauge heights, and the datum areas and gauge record plotted to time abscissas. On the latter plate are also plotted two profiles of the discharge cross section.

* 3363 was used prior to February 15, 1889.

Results of discharge observations, Mississippi River, at Arkansas City, Ark., 1889.

Date.	Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.					
			Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1889.	*Feet.*	*Feet.*	*Square feet.*	*Square feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Square feet.*	*Feet.*	*Cubic feet.*		
Jan. 22	33.45	+0.80	183,640	211,638	54.5	62.3	81.0	3,371		4.298	789,225		Meter.
23	34.10	+0.75	185,978	211,784	55.2	62.4	83.0	3,371	+ 146	4.805	893,714		Do.
24	34.68	+0.65	190,945	214,795	56.6	63.3	83.0	3,372	+ 3,011	4.444	848,555		Do.
25	35.20	+0.45											Do.
26	35.45	+0.25											Do.
27	35.50	+0.05											Do.
28	35.25	−0.25	191,391	213,319	56.7	62.8	85.0	3,373	− 1,476	4.707	900,919	VIII—30	Do.
29	35.05	−0.30	192,706	215,309	57.1	63.4	85.0	3,373	+ 1,990	4.326	833,659	VIII—10	Do.
30	34.55	−0.40	191,040	215,329	56.7	63.4	85.5	3,372	+ 20	4.421	844,502	II—5	Do.
31	34.10	−0.45	189,542	215,348	56.2	63.4	86.0	3,372	+ 19	4.302	815,354	XI—15	Do.
Feb. 1	33.65	−0.45											Do.
2	33.52	−0.20	187,332	215,094	55.6	63.4	84.5	3,371	− 254	4.542	850,838	II—3	Do.
3	33.30	−0.15											Do.
4	33.30	0.00	185,374	213,877	55.0	63.0	85.5	3,371	− 1,217	4.288	794,911		Do.
5	33.35	+0.05											Do.
6	33.50	+0.20	179,841	207,671	53.3	61.2	83.0	3,372	− 6,206	4.412	793,375		Do.
7	33.76	+0.30	178,559	205,512	53.0	60.5	81.5	3,372	− 2,159	4.375	781,219	IV—15	Do.
8	33.86	+0.05	179,757	206,373	53.3	60.8	83.0	3,372	+ 861	4.108	738,416	IV—15	Do.
9	33.80	−0.10	181,426	208,243	53.8	61.3	83.0	3,371	+ 1,870	4.261	773,052	XI—20	Do.
10	33.55	−0.25											Do.
11	33.07	−0.55	175,670	204,949	52.1	60.4	82.0	3,371	− 3,294	4.106	721,228	VII—5	Do.
12	32.25	−0.80	175,206	207,248	52.0	61.0	81.5	3,370	+ 2,290	4.111	720,230	VII—5	Do.
13	31.10	−1.10											Do.
14	29.95	−1.30	167,948	207,740	49.9	61.2	78.0	3,368	+ 492	3.722	625,057	III—10	Do.
15	28.23	−1.40	160,195	205,761	47.7	60.6	78.5	3,360	− 1,979			III—5	Do.
16	26.85	−1.35	142,706	192,845	42.7	56.8	68.5	3,341	−12,916	3.576	510,287	VI—3	Do.
17	25.40	−1.65											Do.
18	24.10	−1.45	133,014	192,319	40.0	56.6	67.5	3,326	− 526			IX—20	Do.
19	22.67	−1.35	128,054	193,018	38.8	56.9	63.0	3,321	+ 699	3.225	415,822	XII—12½	Do.
20	21.53	−1.15	125,317	193,153	38.0	56.9	66.0	3,296	+ 135	3.240	406,072	II—10	Do.
21	20.61	−0.90	125,167	196,035	38.1	57.7	65.0	3,285	+ 2,882	3.232	404,531	XII—3	Do.
22	20.20	−0.35	123,943	196,164	37.7	57.8	65.5	3,284	+ 129	3.214	398,403	III—3	Do.
23	21.02	+1.00	127,570	197,084	38.8	58.1	66.0	3,285	+ 920	3.405	434,361	XII—20	Do.
24	23.50	+2.30											Do.
25	25.53	+2.30	143,482	198,012	43.1	58.3	69.0	3,327	+ 928	3.708	531,990	X—5	Do.
26	27.59	+1.95	148,096	195,762	44.3	57.7	73.5	3,346	+ 2,250	3.962	586,734	II—5	Do.
27	29.25	+1.70	156,287	196,893	46.6	58.4	73.5	3,353	+ 2,681	3.889	607,756	II—2	Do.
28	30.67	+1.35	160,090	197,484	47.7	58.2	74.0	3,359	− 959	3.967	635,103	II—2	Do.
Mar. 1	32.00	+1.20										Calm	Do.

2	32.88	+0.85	168,314	198,408	49.9	58.4	77.5	3,372	+ 960	4.150	698,573		Do.
3	33.55	+0.70											Do.
4	33.76	+0.30	167,612	194,568	49.6	57.3	78.0	3,376	− 8,885	4.409	738,923	IX—5	Do.
5	34.08	+0.25	168,417	194,298	49.9	57.2	77.5	3,376	− 275	4.214	709,707	IX—15	Do.
6	34.53	+0.50	172,071	196,429	51.0	57.9	78.5	3,379	+ 2,136	4.345	747,041	V—10	Do.
7	34.86	+0.25	172,764	196,008	51.2	57.7	78.5	3,376	− 421	4.340	749,723	IX—12½	Do.
8	35.00	+0.15	172,162	194,934	51.0	57.4	78.0	3,377	− 1,074	4.330	745,442	XI—10	Do.
9	34.96	0.00	173,814	196,721	51.5	57.9	78.0	3,377	+ 1,787	4.187	727,761	VIII—8	Do.
10	34.85	−0.15											Do.
11	34.63	−0.20	174,967	198,967	51.8	58.6	79.0	3,377	+ 2,266	4.176	730,743	XII—2	Do.
12	34.18	−0.50	174,508	200,047	51.7	58.9	81.0	3,376	+ 1,060	4.121	719,228	XI—2	Do.
13	33.61	−0.55	171,469	198,930	50.8	58.6	77.0	3,375	− 1,117	4.072	698,281		Do.
14	32.90	−0.75	168,204	198,060	49.9	58.3	74.5	3,374	− 870	4.038	679,285	Calm	Do.
15	32.11	−0.80	166,767	199,282	49.5	58.7	77.5	3,370	+ 1,222	4.003	667,581	VI—10	Do.
16	31.28	−0.80	162,766	198,065	48.4	58.3	76.5	3,363	− 1,217	3.898	634,381	VII—5	Do.
17	30.35	−0.90											Do.
18	29.80	−0.55											Do.
19	29.08	−0.70	154,928	197,771	46.2	58.2	73.5	3,352	− 294	3.774	584,724	XI—12	Do.
20	28.61	−0.50	151,785	196,035	45.4	57.7	73.5	3,344	− 1,736	3.693	560,548	X—3	Do.
21	28.05	−0.60	150,494	196,616	45.1	57.9	73.0	3,339	+ 581	3.721	559,923	X—4	Do.
22	27.46	−0.60	147,806	195,901	44.3	57.7	71.5	3,337	− 715	3.620	535,052	I—8	Do.
23	26.94	−0.50	147,378	197,210	44.2	58.1	72.0	3,335	+ 1,309	3.556	523,559	XI—5	Do.
24	26.65	−0.25											Do.
25	26.21	−0.40	144,973	197,244	43.5	58.1	70.5	3,334	+ 34	3.574	518,191	X—10	Do.
26	26.15	−0.05	144,894	197,366	43.5	58.1	70.5	3,334	+ 122	3.508	508,266	X—6	Do.
27	27.07	+0.65	147,695	197,093	44.3	58.1	71.0	3,336	− 273	3.715	548,655	V—5	Do.
28	28.41	+1.80	152,389	197,308	45.6	58.1	72.0	3,344	+ 215	3.899	594,094	XI—20	Do.
29	30.16	+1.60	157,690	196,741	47.0	58.0	74.0	3,355	− 567	3.976	626,972	II—10	Do.
30	31.24	+1.10	160,617	196,051	47.8	57.7	74.0	3,363	− 690	3.997	641,959	V—6	Do.
31	31.85	+0.50											Do.
Apr. 1	32.09	+0.20	163,294	195,876	48.5	57.7	75.0	3,370	− 175	4.057	662,452	X—12	Do.
2	32.10	+0.05	164,065	196,613	48.7	57.9	75.0	3,370	+ 737	3.998	655,934	IV—5	Do.
3	32.00	−0.10											Do.
4	31.75	−0.25	164,658	198,383	48.9	58.4	75.0	3,368	+ 1,770	3.993	657,464	I—5	Do.
5	31.40	−0.35	161,659	196,556	48.1	57.9	73.5	3,364	− 1,827	3.871	625,704	I—5	Do.
6	30.92	−0.40	160,870	197,366	47.9	58.1	73.0	3,356	+ 810	3.840	617,692	XII—10	Do.
7	30.45	−0.55											Do.
8	29.93	−0.55	156,507	196,329	46.7	57.8	72.5	3,354	− 1,037	3.733	584,234	IX—5	Do.
9	29.38	−0.45	159,303	200,969	47.5	59.2	74.5	3,352	+ 4,640	3.704	590,071		Do.
10	29.23	−0.20	155,646	197,816	46.4	58.3	73.5	3,352	− 3,153	3.676	572,101		Do.
*11	28.89	−0.30	153,858	197,171	45.9	58.1	73.5	3,352	− 645	3.739	575,218	VI—20	Do.
12	28.59	−0.35	152,437	196,754	45.6	58.0	72.5	3,344	− 417	3.787	577,328	V—20	Do.
†13	28.12	−0.45	150,587	196,475	45.1	57.9	72.5	3,340	− 279	3.628	545,538	III—6 to 20	Do.
14	27.70	−0.45											Do.
15	27.14	−0.60	146,868	196,032	44.0	57.7	72.0	3,336	− 448	3.538	518,825	XII—8	Do.
16	26.59	−0.50	144,939	195,941	43.5	57.7	70.0	3,335	− 91	3.521	510,298	II—8	Do.
17	26.04	−0.60	142,985	195,823	42.9	57.7	69.5	3,333	− 118	3.432	490,663	III—6	Do.
18	25.44	−0.50	140,332	195,174	42.1	57.5	68.5	3,332	− 649	3.413	478,933	III—9	Do.
19	25.03	−0.45	137,961	194,167	41.4	57.2	69.0	3,329	− 1,007	3.314	457,162	III—12 to 5	Do.
20	24.55	−0.55	135,174	192,979	40.6	56.8	68.5	3,327	− 1,188	3.301	446,211		Do.

* Water very rough. † Rain and hail storm.

Results of discharge observations, Mississippi River, Arkansas City, Ark., 1889—Continued.

Date.	Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.					
			Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1889.	*Feet.*	*Feet.*	*Square feet.*	*Square feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Square feet.*	*Feet.*	*Cubic feet.*		
Apr. 21	24.25	−0.25											Meter.
22	24.27	−0.00	134,475	193,212	40.4	56.9	67.0	3,326	+ 233	3.312	445,337	XI—5	Do.
23	24.50	+0.30	133,873	191,845	40.2	56.5	66.5	3,327	− 1,367	3.398	454,846	Variable—4	Do.
24	24.84	+0.30	135,676	192,516	40.8	56.7	67.0	3,329	+ 671	3.449	467,880	Var.—Var.	Do.
25	25.18	+0.40	136,519	192,226	41.0	56.6	67.0	3,330	− 290	3.477	474,715	IX—5	Do.
26	25.63	+0.45	136,461	190,668	41.0	56.2	67.0	3,332	− 1,558	3.487	475,849	XI—3	Do.
27	26.38	+0.75	139,156	190,859	41.7	56.2	69.0	3,334	+ 191	3.595	500,330	X—5	Do.
28	27.30	+0.85											Do.
29	27.87	+0.55	144,289	191,013	43.2	56.3	71.0	3,339	+ 154	3.638	524,935	IV—5	Do.
30	28.10	+0.25											Do.
May 1	27.86	−0.30	145,288	192,046	43.5	56.6	71.5	3,339	+ 1,033	3.587	521,209	XI—6	Do.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT WILSON POINT, LOUISIANA, 1887-1889.

All gauge readings at the discharge section are referred to the zero of Lake Providence gauge. Datum was assumed at 41.83 feet, the same as in the observations of 1883-1885. Datum width was taken as 3,555 feet for 1887 and 1888, and 3,646 feet for 1889. For the observations of 1887-'88 the first computation of water areas was checked by planimeter measurements, the sounding notes not being obtainable; and the water widths were scaled from the plotted cross section.

The methods used in finding the other quantities tabulated have already been described in the memoranda accompanying the final reduction of discharge observations of 1883-1885.

The results of reduction in Secretary's office of observations for rating the meters that were used in observing velocities are given in the following table:

Designation of meter.	Date and locality of rating observations.	Number of observations.	*a*	*b*	Mean error of observations.	Mean error of *a*	Mean error of *b*
Not given	Apr. 18, 1887, Old River Lake.	10	+1.9921	+0.3769	+0.0825	±0.0251	±0.0832
Do	Apr. 23, 1887, Old River Lake.	15	+1.8941	+0.3448	±0.0671	±0.0145	±0.0493
Price, No. 5.	July 4, 1889, near Ashton, La.	11	+4.0704	+0.0417	±0.1735	±0.0810	±0.1341

Combining the results of April 18 and 23, 1887, by weighting the constants inversely as the squares of their mean errors we have

$$y = 1.9186\,x + 0.353,$$

which was the equation used for reducing the observations at Arkansas City and Wilson Point, 1887 and 1888.

The equation used for computing the discharges of July 3-5, 1889, was

$$y = 4.0704\,x + 0.0417.$$

Results of discharge observations, Mississippi River, Wilson Point, La., 1887, 1888, and 1889.

[Results of final computation in Secretary's office of a series of discharge observations made at this station in 1883–1885, gauge reading from 11.58 to 41.83 feet, are published in Report of Chief of Engineers, 1890, page 3170.]

Date.	Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.					
			Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1887.	Feet.	Feet.	Sq. ft.	Sq. ft.	Feet.	Feet.	Feet.	Feet.	Sq. ft.	Feet.	Cubic feet.		
Apr. 19	27.23	−1.28	139,309	191,139	39.3	58.8	60.0	3,545	....	3.888	541,673	....	Meter.
1888.													
Apr. 22	41.63	+0.12	179,815	180,526	50.7	50.9	72.0	3,550	....	6.452	1,160,172	....	Do.
23	41.68	+0.07	177,905	178,488	50.1	50.3	71.0	3,550	−2,088	6.392	1,137,256	....	Do.
24	41.63	+0.02	174,672	175,383	49.1	49.3	69.0	3,555	−3,055	6.036	1,054,318	....	Do.
25	41.63	0.00	181,421	182,132	51.0	51.2	73.0	3,556	+6,749	6.000	1,088,450	....	Do.
26	41.56	−0.07	188,075	189,084	53.0	53.2	72.0	3,550	+6,902	6.374	1,198,871	....	Do.
27	41.43	−0.18	179,252	180,671	50.6	50.8	73.0	3,542	−8,363	6.250	1,120,357	....	Do.
1889.													
July 3	33.03	−0.18	133,739	165,736	36.9	45.5	75.0	3,626	....	6.388	854,370	XI—7	Do.
4	32.70	−0.30	132,462	165,659	36.5	45.4	76.5	3,626	−77	6.489	859,553	I—3	Do.
5	32.13	−0.58	129,388	164,648	35.7	45.2	76.5	3,624	−1,011	6.116	791,386	II—8 to 15	Do.

EXTRACTS FROM REPORT BY MR. E. C. TOLLINGER, ASSISTANT ENGINEER, CHIEF OF PARTY, UPON DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT WILSON POINT, LOUISIANA, JULY 3 TO 5, 1889.

UNITED STATES ENGINEER OFFICE,
Ashton, La., July 23, 1889.

* * * * * * *

Outfit.—The launch (No. 3), meter (Price, No. 5), batteries, etc., were the same as used at Arkansas City, Ark., during the past season. A main fluke to replace one broken off February 22, 1889, was put on the propeller on the 2d instant. Except under favorable conditions the launch needs careful handling by men familiar with its eccentricities to insure safety. As will be seen below, the conditions were not favorable, but each unfavorable experience lessened the danger of its repetition.

Party.—The party consisted of J. J. Hoopes (present by invitation); E. C. Tollinger, assistant engineer; Birdwell, pilot; Tupper, steam engineer; Jas. H. Bryan, leadsman; and a fireman. The registrations were counted by the assistant engineer; the time noted and announced and the meter lowered, etc., by the leadsman. The assistant engineer and the leadsman were familiar with the work, the launch, etc., but the remainder of the crew were not familiar with either.

Stage of water.—The rise had reached its highest point on the 1st instant, the gauge reading * 29.40. Our observations were made therefore on the first 3 days of the fall.

Other conditions.—Considerable drift was moving throughout the period covered by our observations.

Location.—The discharge section was at Wilson Point, La, and on the same † line used by Mr. Arthur Hider, United State assistant engineer, in 1887, but was somewhat lengthened by caving on the Louisiana side. The same ranges were used except that one was added on the Louisiana shore.

Observations.—The soundings were taken from skiff launched to the starboard side of the launch, and from the Louisiana to the Mississippi shore. They were taken at the stations, and half way between stations. The current was so strong and the water so deep that quite a number of drifting soundings had to be made.

Velocities.—The observations of the velocities were made at the stations, and from the Mississippi to the Louisiana side.

The meter boom was first lowered at a horizontal angle of 45 degrees with the launch, but was afterward worked directly astern in the deeper water, and the boom to which the guy rope was attached pointed about directly forward. This course lessened the danger of breaking the forward boom and lessened the liability of the current pulling the meter cord off of the well wheel attached to the main boom.

The meter weight was not heavy enough to sink it to the original depth [six-tenths from the surface] in the deepest and swiftest water; two or three stations were therefore taken at mid-depth. * * *

Rating the meter.—The meter was rated on the evening of July 4, in still water, just above the fleet near Ashton, La. The water being still, all the observations except one were, for convenience, made in the same direction. The length of base was 300 feet. * * *

CAPT. WM. T. ROSSELL,
Corps of Engineers, U. S. A.
Memphis, Tenn.

EXTRACTS FROM REPORT BY MR. WM. GERIG, ASSISTANT ENGINEER, CHIEF OF PARTY, UPON DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER AT NEW MADRID, MISSOURI, 1888-'89, AND UPON THE OFFICE COMPUTATION.

MEMPHIS, TENN., *September* 5, 1889.

* * * * * * *

The party at this station consisted of one assistant engineer, one steam engineer, one steersman, and two boatmen.

Observations were made upon two sections about 1¼ miles apart. The first was called the high-water section and was about 5 miles below New Madrid. At the end of the section on the right bank a base line 4,829 feet long was measured nearly at

* 33.23, referred to the zero of the Lake Providence gauge. (Secretary Mississippi River Commission.)

† This is apparently also the line used for discharge section during the observations of 1883, 1884, and 1885. (Secretary Mississippi River Commission.)

right angles to the section. On each bank a series of radial signals was set, determining lines which intersected the section at points 300 feet apart called velocity stations. Signals were also set on the section to determine the river width; the distance between these signals being 6,053 feet. Distances from the water's edge to these signals were observed each day which determined the river width. In the system of intersecting ranges, on the right bank, the pivot signal was 5,302 feet from the section and a perpendicular from it intersected the section 1,084 feet from signal B on the prolonged section. The other signals were placed between the pivot signal and section and on the base line. Secondary signals were set between them to locate the soundings.

As the lower stages of the river were reached in December, several undesirable features devoloped in the high-water section, the presence of bars near both banks made the water too shallow to allow the launch to be used, and caused the current to be deflected toward the middle of the river so that it was no longer normal to the section; as the water continued falling the bars appeared and a pocket was formed near the left bank in which there was no current. It was decided therefore to change the section and a low-water section was located about 1¼ miles above the high-water section.

The manner of locating velocity and sounding stations was similar to that of the high-water section. The points at the end of this section were designated Z and X and the distance between them was 4,141.8 feet. The pivot signal was on the left bank and at a perpendicular distance from the prolonged section line of 1,638 feet; the intersecting point was 1,147 feet from X, the minimum angle for locating the section being 30° 45′.

The river rose in January, and on the 19th the high-water section was occupied and used till February 13, and then the low-water section till February 22.

The instruments in use consisted of Price meter No. 10, a Morse register, a break circuit clock, electric batteries, transit, level, sounding leads, lines, etc. The meter was the well known Price meter which has been in use on the river for several years. * * * The meter gave no trouble except once when the gutta-percha which made the break had worn down so that the electric current was not broken. The gutta-percha was removed as well as the other pieces which held it in position, and then the contact was made on the remaining half of the axis. * * *

Much trouble was caused by the clock, which was a very old one and was frequently out of repair, at which time a watch was used, the time of beginning being marked on the ribbon with a pencil and also that of ending. * * *

The meter circuit was made through a steel sash cord on which the meter was suspended, and through an insulated copper wire which was paid out with the sash cord. A 15-pound sounding lead and a three-eighths inch cotton line were used throughout the season.

Drifting soundings were taken during the highest water, but generally soundings were taken without drifting, since the maximum depth was about 30 feet. * * *

The meter was suspended from a boom 12 feet long at the stern of the launch, the boom projecting over the side and making an angle of about 60° downstream with the axis of the launch. A steel sash cord, three-sixteenths of an inch in diameter, passed around a reel in stern of launch, through a small pully in the end of boom, thence to an iron rod 1 inch in diameter and 2 feet long. To this rod the meter was attached and also a lead weight of about 50 pounds. Attached to the top of the rod was a fine steel piano wire which passed through a pulley in the end of a 20-foot boom in the bow of the launch and thence to a reel. By paying out proper lengths of standing and guy lines, the meter could be immersed to any desired depth. * * *

The coefficients to be used in reducing the registrations of the meter to velocity in feet per second were determined by causing the meter to move through still water over a known distance at various velocities, the time and number of registrations being noted. A float was anchored in still water upon which a beam was revolved at the end of which the meter was attached. The beam was of such a length that in making one revolution the meter traversed 100 feet. The meter circuit was made from the battery to the stand on which the arm was revolved, thence to the meter, thence back by a copper wire through the register to the other pole of the battery. The clock circuit was so arranged that when the revolving arm arrived at a certain point the circuit was made and the time registered until the arm had made a revolution when the circuit was broken and the time ceased to be recorded. This was done by a small brass arm extending up so that the revolving arm could touch it and move it till it touched another piece of brass or nickel and thus made the connection. By this method time of beginning and ending could easily be measured to one-twentieth of a second if the connection was made during the half second

NOTE.—For a full description of the meter and outfit and the methods of computation, see Annual Report Chief of Engineers, 1887, pp. 2821–3. (Secretary Mississippi River Commission.)

when the circuit was made, otherwise it could only be measured to the nearest half second. The revolution of the meter could be measured equally as accurately. * * *

The rating observations were reduced by the method of least squares. The following are the results of the rating of the meter which were adopted for use:

Date.	No. of observations.	*a*	*b*	Mean error of observations.
November 23, 1888	22	3,860	+0.215	±0.018
April 17, 1889	38	3,920	+0.100	±0.020

A number of ratings were made, but rejected on account of large errors which were due to the swivel not turning on its axis in changing the direction of the revolution of the arm, and thereby causing the revolutions of the meter to be retarded, and also that the brass connections upon which the arm revolved were nearly worn out, so that false registrations were made. On April 17 all these errors were eliminated and the results are very accurate.

The formulæ used in reducing were, till December 31, 1888,

$$y = 3.86\,x + 0.22, \text{ and afterward } y = 3.92\,x + 0.10.$$

The lead line was tested every morning before using, and corrected by retagging if in error. It was also tested at close of work and errors, if any, compensated by correction of soundings.

The number of seconds that the meter continued to spin was noted before and after each day's work, and the mean recorded. * * *

In the final reduction the widths were calculated and the soundings plotted on cross-section sheets, as were also the velocities. The velocities were reduced by the formulæ adopted and recorded in the note books. The total area was divided into partial areas of 500 feet width; these partial areas were calculated by counting the squares and were multiplied by the mean velocities of the partial areas which were taken from the cross-section sheets. The product was the partial discharge, and the sum of the partial discharges gave the total discharge, and this divided by the total area gave the mean velocity. The counting of the registrations was done in the field and checked after each day's work.

The measurements for velocity were taken at six-tenths depth. The length of the observations varied from 150 seconds to 300 seconds, though generally the duration was 150 seconds. The computation of velocities from the given times and registrations was performed by means of the tables prepared for the purpose. The results of computation were copied in a tabular form accompanying this report and also into the note books.

The gauge readings correspond to the mean time of observation. The gauge was read at the time of beginning and ending of each day's work which was about 8 a. m. and 4 p. m. The rise or fall in 24 hours is the difference in the mean gauge reading for that day and the preceding one.

The computation of datum areas has been made in the following manner: For the high-water section the datum was assumed to correspond to the gauge reading of 25.6 feet. The datum width was taken as 5,967 feet, that being the measured width and gauge reading on February 27, 1889. The slope of the banks down to 20 feet on gauge was uniform, also from 20 feet to 10 feet and below 10 feet, and the datum areas have been computed by the formula:

$$\text{Datum area} = (25.6 - h, \frac{5967 + w}{2} + \text{water area, where } h = \text{gauge and } w = \text{width.}$$

The formula between 20 feet and 10 feet on gauge becomes:

$$\text{Datum area} = (25.6 - 20, \frac{5967 + 5930}{2} + (20 - h)\,\frac{5930 + w}{2} + \text{water area}$$

$$= 33312 + (20 - h)\,\frac{5930 + w}{2} + \text{water area,}$$

in which 5930 feet is width at 20-foot stage.

For stages below 10 feet the formula is:

$$\text{Datum area} = 33312 + (20 - 10)\,\frac{5930 + 5820}{2} + (10 - h)\,\frac{5820 + w}{2} + \text{water area.}$$

$$= 9206.2 + (10 - h)\,\frac{5820 + w}{2} + \text{water area.}$$

The low-water section datum was assumed as the surface of the water on January 18, the gauge reading being 21.62. The width on that day was 4,023 feet, which was taken as the datum width. The slope of the banks change at 20 feet, 15 feet, and 10 feet stages, and the widths at these stages are 4,009, feet, 3,965 feet, and 3,911 feet. The formula used is:

$$\text{Datum area} = (21.62 - h)\,\frac{4023 + w}{2} + \text{water area.}$$

Between stages 15 feet and 20 feet the formula becomes:

$$\text{Datum area} = (21.62 - 20)\,\frac{4023 + 4009}{2} + (20 - h)\,\frac{4009 + w}{2} + \text{water area}$$

$$= 6506 + (20 - h) + \frac{4009 + w}{2} + \text{water area.}$$

Between 15 feet and 10 feet:

$$\text{Datum area} = 6506 + (20 - 15)\,\frac{4009 + 3965}{2} + (15 - h)\,\frac{3965 + w}{2} + \text{water area}$$

$$= 26441 + (15 - h)\,\frac{3965 + w}{2} + \text{water area.}$$

Below 10 feet:

$$\text{Datum area} = 26441 + (15 - 10)\,\frac{3965 + 3911}{2} + (10 - h)\,\frac{3911 + w}{2} + \text{water area}$$

$$= 46131 + (10 - h)\,\frac{3911 + w}{2} + \text{water area.}$$

Mean depth has been obtained by dividing the water area by the width, and mean datum depth has been obtained by dividing the datum area by the datum width. Maximum depth was taken directly from the notes. Scour or fill has been obtained by taking the difference of the datum areas; scour is indicated by the positive sign.

The direction of the wind is indicated by dividing the horizon into twelve parts, and numbering the parts the same as the hours on a clock dial, XII being upstream and indicating a downstream wind.

A plot has been made with the mean velocities and discharges of both sections as ordinates, and the gauge heights as abscissas. The scales for each system are shown on the plot. * * *

Herewith also find a tracing showing the location of the sections.

The entire work has been checked in various ways, and great care has been taken to eliminate all errors of computation.

* * * * * * *

Capt. SMITH S. LEACH,
Corps of Engineers, U. S. A.

*Results of discharge observations, Mississippi River, New Madrid, Mo., 1888–'89.**

Date.	New Madrid gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	Reading.	Rise or fall in the preceding 24 hours.†	Area.		Depth.			Width.					
			Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1888.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.		
Nov. 28	18.50	....	....	....	....	....	30.0	5,915	....	....	....	I—Slight	Meter.
29	17.30	−1.20	....	....	....	....	28.0	5,913	....	....	....	XII—Slight	Do.
30	16.30	−1.00	....	....	....	....	31.0	5,908	....	....	....	XII—Strong	Do.
Dec. 1	15.25	−1.05	125,650	187,068	21.3	31.3	30.0	5,905	....	3.460	434,751	X—Slight	Do.
3	12.80	−2.45	112,320	188,147	19.1	31.5	29.6	5,880	+1,079	3.383	379,995	X—Slight	Do.
4	12.05	−0.75	103,004	183,237	17.5	30.7	29.0	5,873	−4,910	3.255	335,220	IX—Slight	Do.
5	11.30	−0.75	100,195	184,837	17.1	31.0	28.0	5,870	+1,600	3.219	322,582	XI—Strong	Do.
6	10.35	−0.95	97,415	187,642	16.6	31.4	26.0	5,865	+2,805	3.140	305,854	VIII—Mild	Do.
7	9.70	−0.65	94,500	188,330	16.4	31.6	25.5	5,772	+ 688	3.234	305,577	V—Strong	Do.
8	9.20	−0.50	89,840	186,493	15.8	31.3	25.0	5,657	−1,837	3.164	284,209	VI—Slight	Do.
10	8.62	−0.57	84,200	183,879	16.6	30.8	23.0	5,301	−2,614	3.076	247,362	II—Mild	Do.
11	8.32	−0.30	80,146	181,491	16.0	30.4	22.5	5,275	−2,388	3.082	235,282	XII—Mild	Do.
12	8.04	−0.29	75,867	178,907	15.2	30.1	22.5	5,267	−2,584	3.129	223,009	XII—Mild	Do.
13	7.74	−0.30	73,910	128,844	19.1	32.0	26.0	3,868	(‡)	2.951	218,082	XII—Mild	Do.
14	7.44	−0.30	73,190	129,285	19.2	32.1	25.0	3,866	+ 441	2.983	218,359	V—Strong	Do.
15	7.20	−0.24	73,125	130,145	19.0	32.3	25.0	3,866	+ 860	3.030	221,208	V—Very strong	Do.
17	6.90	−0.30	72,820	131,000	18.8	32.6	25.5	3,863	+ 855	2.950	214,623	XI—Strong	Do.
18	6.90	0.00	75,258	133,438	19.5	33.2	26.5	3,862	+2,438	2.890	217,282	X—Slight	Do.
19	7.00	+0.10	74,226	132,021	19.2	32.8	26.0	3,864	−1,417	2.950	218,922	XII—Slight	Do.
20	7.19	+0.19	75,760	132,825	19.6	33.0	25.5	3,864	+ 804	2.975	225,394	VII—Strong	Do.
21	7.47	+0.29	75,935	131,883	19.7	32.7	26.0	3,865	− 942	3.020	229,446	XI—Mild	Do.
22	8.15	+0.67	78,545	131,880	20.3	32.7	26.7	3,878	− 3	3.040	238,743	VIII—Mild	Do.
24	8.90	+0.75	82,015	132,436	21.1	32.9	27.5	3,890	+ 556	3.177	260,486	VI—Mild	Do.
25	9.13	+0.23	85,090	134,617	21.8	33.5	27.5	3,895	+2,181	3.200	271,930	Calm	Do.
26	9.26	+0.13	....	....	....	....	....	....	....	....	....	VI—Very strong	Do.
27	9.62	+0.26	85,295	132,907	21.8	33.0	28.0	3,908	−1,710	3.221	274,733	X—Slight	Do.
28	10.23	+0.61	87,705	132,935	22.4	33.0	28.3	3,913	+ 28	3.290	288,182	Calm	Do.
29	10.85	+0.62	89,895	132,691	22.9	33.0	30.0	3,917	− 244	3.360	301,806	Calm	Do.
31	12.08	+1.23	95,305	133,283	24.2	33.1	31.0	3,935	+ 592	3.438	325,708	XII—Mild	Do.
1889.													
Jan. 1	12.20	−0.12	97,375	134,879	24.7	33.5	32.1	3,938	+1,596	3.450	335,947	XII—Mild	Do.
2	12.13	−0.07	97,150	134,927	24.7	33.5	32.0	3,936	+ 48	3.416	331,898	VI—Mild	Do.
3	11.91	−0.22	96,690	135,346	24.6	33.6	31.5	3,934	+ 419	3.355	324,360	Calm	Do.
4	11.39	−0.52	93,330	134,016	23.8	33.3	30.5	3,926	−1,330	3.316	309,476	V—Mild	Do.
5	10.98	−0.41	92,005	134,305	23.4	33.4	29.5	3,924	+ 289	3.300	303,524	X—Slight	Do.
7	11.17	+0.19	91,940	133,486	23.5	33.2	29.5	3,922	− 819	3.335	306,580	V—Slight	Do.

* From reduction at office of 1st District Engineer.

† Where a day is omitted the rise or fall given on the following day is for 48 hours.

‡ Low-water section occupied from December 13 to January 18 and from February 14 to 21, inclusive.

Results of discharge observations, Mississippi River, New Madrid, Mo., 1888-'89—Continued.

Date.	New Madrid gauge. Reading.	New Madrid gauge. Rise or fall in the preceding 24 hours.	Cross section of discharge. Area. Water.	Area. Below datum.	Depth. Mean.	Depth. Mean datum.	Depth. Maximum.	Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*		
Jan. 8	11.60	+0.43	93,645	133,502	23.9	33.2	30.0	3,926	+ 16	3.380	316,141	V—Strong	Meter.
10	13.35	+1.75	99,765	132,735	25.3	33.0	32.0	3,949	− 767	3.560	354,724	VI—Slight	Do.
11	14.95	+1.60	104,955	131,594	26.5	32.7	32.5	3,965	−1,141	3.650	383,172	XI—Slight	Do.
12	16.95	+2.00	111,295	129,983	28.0	32.3	34.0	3,979	−1,611	3.990	444,401	V—Slight	Do.
14	19.75	+2.80	124,850	131,858	30.7	32.7	38.0	4,007	+1,875	4.500	556,883	Calm	Do.
15	20.28	+0.53	128,900	134,281	32.1	33.4	38.7	4,010	+2,423	4.480	575,539	V—Strong	Do.
16	20.57	+0.29	....	....	....	....	....	4,014	....	....	....	V—Very strong	Do.
17	20.97	+0.40	130,205	132,817	32.4	33.0	40.0	4,015	−1,464	4.580	595,303	XII—Slight	Do.
18	21.62	+0.65	133,155	133,155	33.1	33.1	40.0	4,023	+ 338	4.540	605,016	XII—Slight	Do.
19	22.20	+0.58	169,950	190,210	28.5	31.9	37.0	5,951	....	3.810	645,953	XII—Mild	Do.
21	24.10	+1.90	177,085	186,026	29.7	31.2	37.5	5,955	−4,184	3.906	691,550	XII—Mild	Do.
22	24.53	+0.43	178,255	184,635	30.0	30.9	38.0	5,959	−1,391	3.940	702,290	VI—Strong	Do.
23	24.15	−0.38	175,895	184,539	29.5	30.9	37.0	5,955	− 96	3.930	692,823	Calm	Do.
24	23.35	−0.80	173,840	187,249	29.2	31.4	38.0	5,952	+2,710	3.850	670,076	XII—Slight	Do.
25	22.20	−1.15	168,820	189,065	28.4	31.7	37.4	5,942	+1,816	3.820	644,896	Calm	Do.
26	20.90	−1.30	159,105	187,075	27.0	31.4	35.0	5,936	−1,990	3.720	591,046	XII—Slight	Do.
28	18.85	−2.05	146,960	187,087	24.8	31.4	33.0	5,928	+ 12	3.625	532,707	XI—Slight	Do.
29	18.65	−0.20	145,330	186,641	24.5	31.3	32.3	5,923	− 446	3.564	518,898	XI—Slight	Do.
30	19.10	+0.55	145,870	184,516	24.6	30.9	33.5	5,925	−2,125	3.624	528,652	XII—Strong	Do.
31	19.93	+0.83	150,285	184,012	25.3	30.8	33.5	5,930	− 504	3.695	555,262	XI—Strong	Do.
Feb. 1	20.60	+0.67	156,050	185,805	26.3	31.1	35.0	5,985	+1,793	3.680	574,319	V—Mild	Do.
2	21.38	+0.78	161,040	186,187	27.1	31.2	34.5	5,940	+ 382	3.718	597,961	Calm	Do.
4	22.45	+1.07	166,745	185,509	28.0	31.1	34.8	5,946	− 678	3.830	638,696	VIII—Strong	Do.
5	22.48	+0.03	166,735	185,827	28.0	31.1	35.3	5,951	− 182	3.837	639,729	XI—Strong	Do.
6	22.03	−0.45	164,820	186,092	27.7	31.2	35.0	5,950	+ 765	3.830	631,680	XI—Mild	Do.
7	21.12	−0.91	158,255	184,918	26.7	31.0	34.8	5,936	−1,174	3.873	612,887	VII—Strong	Do.
8	19.90	−1.22	148,855	182,759	25.1	30.6	32.5	5,926	−2,159	3.590	534,501	VI—Mild	Do.
9	18.75	−1.15	143,375	184,115	25.9	30.9	32.0	5,917	+1,356	3.547	508,610	XII—Mild	Do.
11	16.53	−2.22	125,460	179,366	21.8	30.1	29.5	5,902	−4,749	3.468	434,511	XI—Strong	Do.
12	15.50	−1.03	114,860	174,776	19.5	29.8	29.0	5,894	−4,593	3.386	387,841	X—Mild	Do.
13	13.90	−1.60	110,025	179,375	18.7	30.1	28.0	5,887	+4,599	3.391	373,143	VIII—Strong	Do.
14	12.15	−1.85	....	....	....	....	....	3,932	(†)	....	....	Fog	Do.
15	11.30	−0.85	....	....	....	....	....	....	....	....	....	do	Do.
16	10.53	−0.77	84,805	128,880	21.6	32.0	28.0	3,925	....	3.493	295,178	VIII—Slight	Do.
18	10.09	−0.53	84,370	130,501	21.5	32.4	27.7	3,914	+1,621	3.483	293,864	X—Moderate	Do.
19	11.55	+1.55	88,825	128,880	22.7	32.0	29.0	3,926	−1,621	3.536	314,101	X—Slight	Do.
20	14.75	+3.20	104,170	131,602	26.3	32.7	32.7	3,965	+2,722	3.981	414,847	VI—Slight	Do.
21	18.30	+3.55	118,205	131,517	29.6	32.7	36.0	3,998	− 85	4.392	519,182	VI—Slight	Do.
22	20.75	+2.45	153,535	182,390	25.9	30.6	34.0	5,930	....	3.815	585,687	XII—Slight	Do.

23	22.40	+1.65										Do.
24	23.80	+1.40	170,565	181,295	29.0	30.4	36.0	5,966	−1,095	4.000	682,280	III—Slight	Do.
25	25.10	+1.30	178,795	181,779	30.0	30.4	38.0	5,965	+ 484	4.031	720,686	II—Slight	Do.
26	25.60	+0.50	185,910	185,910	31.2	31.2	39.0	5,966	+4,181	4.057	754,326	Calm	Do.
27	25.60	0.00	187,650	187,650	31.5	31.5	39.0	5,967	+1,740	4.076	760,899	VI—Slight	Do.
28	25.35	−0.25	187,460	188,952	31.4	31.7	39.5	5,967	+1,302	4.000	749,665	XI—Slight	Do.
Mar. 1	25.00	−0.35	183,670	187,249	30.8	31.4	38.8	5,962	−1,703	4.009	736,346	XII—Slight	Do.
2	24.35	−0.65	179,040	186,499	30.0	31.2	38.0	5,958	− 750	3.940	705,026	I—Slight	Do.
4	22.90	−1.45	168,000	184,087	28.3	30.9	38.0	5,948	−2,412	3.855	647,936	I—Slight	Do.
5	22.70	−0.20	167,240	184,515	28.1	30.9	37.0	5,947	+ 438	3.826	639,938	XI—Mild	Do.
6	22.70	0.00	166,825	184,100	28.0	30.9	37.5	5,947	− 415	3.837	640,172	XII—Slight	Do.
7	22.65	−0.05	167,410	184,983	28.2	31.0	36.7	5,947	+ 883	3.819	639,283	XII—Slight	Do.
8	22.45	−0.20	165,975	184,740	27.9	31.0	38.0	5,944	− 243	3.770	624,932	XI—Mild	Do.
9	21.70	−0.75	163,380	186,589	27.5	31.3	37.5	5,934	+1,849	3.751	612,798	XI—Mild	Do.
11	20.23	−1.47	155,045	186,980	26.2	31.4	35.7	5,927	+ 391	3.651	566,100	VI—Slight	Do.
12	19.65	−0.58	149,510	184,897	25.2	31.0	35.3	5,928	−2,083	3.638	543,910	XII—Slight	Do.
13	19.10	−0.55	145,840	184,483	24.7	30.9	34.7	5,918	− 414	3.628	528,894	VI—Slight	Do.
14	18.80	−0.30	143,645	184,064	24.3	30.8	34.0	5,915	− 419	3.614	519,161	VI—Slight	Do.
15	18.40	−0.40	141,630	184,417	24.0	30.9	33.7	5,914	+ 353	3.559	504,060	VI—Slight	Do.
16	17.95	−0.45	139,050	184,500	23.6	30.9	32.7	5,912	+ 83	3.547	493,232	VI—Slight	Do.
18	17.23	−0.72	131,590	181,404	22.3	30.4	32.0	5,905	−3,096	3.529	463,943	VI—Slight	Do.
19	16.70	−0.53	129,920	182,758	22.0	30.6	31.8	5,904	+1,354	3.602	467,779	XII—Strong	Do.
20	16.50	−0.20	127,375	181,393	21.6	30.4	31.0	5,902	−1,365	3.433	437,374	XII—Mild	Do.
21	16.25	−0.25	125,350	180,843	21.3	30.3	31.5	5,900	− 550	3.402	426,471	XII—Slight	Do.
22	16.18	−0.07	125,115	180,636	21.2	30.3	30.5	5,898	− 207	3.392	424,272	III—Slight	Do.
23	16.75	+0.57	128,280	180,818	21.7	10.3	31.0	5,902	+ 182	3.455	443,187	XII—Slight	Do.
25	18.95	+2.20	141,290	180,822	23.9	30.3	33.0	5,919	+ 4	3.598	508,276	I—Slight	Do.
26	19.37	+0.42	144,300	181,346	24.4	30.4	33.7	5,925	+ 524	3.690	531,697	VI—Slight	Do.
27	19.35	−0.02											
28	19.05	−0.30	143,530	182,473	24.2	30.6	33.3	5,925	+1,127	3.673	527,208	X—Slight	Do.
29	18.63	−0.42	141,100	182,529	23.8	30.6	33.5	5,920	+ 56	3.672	518,084	VI—Moderate	Do.
30	18.03	−0.60	137,770	182,747	23.3	30.6	32.0	5,912	+ 218	3.618	498,321	XII—Slight	Do.
Apr. 1	17.27	−0.76	131,305	180,777	22.2	30.3	31.5	5,909	−1,970	3.573	469,445	XII—Strong	Do.
2	16.78	−0.49	128,520	180,880	21.7	30.3	31.0	5,901	+ 103	3.441	442,305	XII—Slight	Do.
3	16.30	−0.48	126,100	181,289	21.4	30.6	30.3	5,896	+ 409	3.463	436,737	XII—Slight	Do.
4	16.10	−0.20	123,200	179,572	20.9	30.1	30.3	5,896	−1,717	3.420	421,334	XII—Slight	Do.
5	16.08	−0.02	123,100	179,591	21.4	30.1	30.3	5,896	+ 19	3.424	421,725	VI—Mild	Do.
6	16.18	+0.10	123,220	179,119	20.9	30.0	30.3	5,896	− 472	3.441	424,003	I—Mild	Do.
8	16.23	+0.05	123,855	179,460	21.0	30.0	30.5	5,897	+ 341	3.439	425,915	VI—Slight	Do.
9	15.88	−0.35	122,942	180,611	20.9	30.3	30.5	5,894	+1,151	3.418	420,261	VI—Slight	Do.
10	15.47	−0.41	120,450	180,538	20.4	30.2	30.3	5,892	− 73	3.383	407,431	VI—Slight	Do.
11	15.10	−0.37	118,715	180,985	20.2	30.3	29.7	5,890	+ 447	3.382	401,527	VI—Strong	Do.
12	14.75	−0.35	116,740	181,081	19.8	30.4	29.7	5,889	+ 96	3.351	391,134	VI—Strong	Do.
13	14.60	−0.15	115,180	180,400	19.6	30.2	29.7	5,887	− 681	3.295	379,715	XI—Slight	Do.
15	14.10	−0.50	112,140	180,299	19.1	30.2	29.0	5,883	− 101	3.296	369,866	VI—Slight	Do.
16	13.85	−0.25	109,695	179,322	18.7	30.0	28.0	5,880	− 977	3.290	361,620	V—Slight	Do.
17	13.65	−0.20	107,790	178,598	18.4	29.9	27.3	5,880	− 724	3.276	353,167	XII—Slight	Do.
18	14.15	+0.50	108,780	176,648	18.5	29.6	28.0	5,883	−2,150	3.329	362,076	VI—Moderate	Do.

* Where a day is omitted the rise or fall given on the following day is for 44 hours.
† Low-water section occupied from December 18 to January 18 and from February 18 to 21, inclusive.

Results of discharge observations, Mississippi River, New Madrid, Mo., 1888–'89—Continued.

Date.	New Madrid gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	Reading.	Rise or fall in the preceding 24 hours.*	Area.		Depth.			Width.					
			Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1889.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.		
Apr. 19	14.93	+0.78	113,230	176,510	19.2	29.6	28.8	5,892	− 138	3.364	380,901	VI—Mild	Meter.
20	15.65	+0.72	117,095	176,137	19.9	29.5	29.7	5,899	− 373	3.421	401,506	VII—Slight	Do.
22	16.58	+0.93	121,735	175,286	20.6	29.4	31.0	5,905	− 851	3.502	426,389	III—Slight	Do.
23	16.97	+0.42	124,975	176,221	21.2	29.5	31.0	5,908	+ 935	3.512	438,580	III—Slight	Do.
24	17.55	+0.58	128,420	176,238	21.8	29.5	32.0	5,912	+ 17	3.587	460,685	IX—Slight	Do.
25	18.33	+0.78	132,675	175,882	22.4	29.5	33.2	5,919	− 356	3.654	484,839	XI—Slight	Do.
26	18.60	+0.27	136,620	178,229	23.1	29.9	34.0	5,924	+2,347	3.674	501,817	XII—Slight	Do.
27	18.35	−0.25	135,125	178,214	22.8	29.9	33.5	5,921	− 15	3.644	492,323	X—Moderate	Do.
29	16.00	−2.35	122,660	179,631	20.8	30.1	31.5	5,899	+1,417	3.447	422,967	VII—Mild	Do.
30	14.75	−1.25	115,430	179,769	19.6	30.1	29.0	5,890	+ 138	3.363	388,279	XII—Mild	Do.
May 1	13.70	−1.05	108,750	179,263	18.5	30.0	27.8	5,880	− 506	3.291	357,981	XII—Mild	Do.
2	12.70	−1.00	102,420	178,824	17.4	29.9	26.3	5,876	− 439	3.257	333,734	XII—Mild	Do.

* Where a day is omitted the rise or fall given on the following day is for 48 hours.

EXTRACTS FROM REPORT OF MR. C. W. STURTEVANT, ASSISTANT ENGINEER, CHIEF OF PARTY, UPON FIELD WORK OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT HELENA, ARKANSAS, 1888-'89.

MEMPHIS, TENN., *July 29, 1889.*

* * * * * * *

The observations were taken from November 28, 1888, to May 2, 1889, inclusive, upon a section located near the positions of former sections used in 1882 and 1884, and normal to the axis of the current.

Observations for velocity were taken 200 feet apart, and soundings 100 feet apart, from station 0 to station 22½, where the slope of the river bottom was uniform. Between stations 22½ and 25 the bottom was uneven and of steep slope, and soundings were taken 50 feet apart. The section was purposely located to pass tangent to and on the south side of the smokestack of the new cotton compress in South Helena.

The Arkansas end of the section is 1,042 feet below the upper edge of the elevator and was further marked by signals on the bluffs and at river bank.

The Mississippi end of the section is about 50 feet south of the narrow gauge railway, and marked by two signals 700 feet apart.

In the system of intersecting ranges the back or pivot signal was 5,397 feet above the section, and a perpendicular from it intersected the section at station 23, or about 350 feet from the Arkansas shore line, the front signals being so placed as to make the ranges intersect the section at each velocity station, or every 200 feet. The minimum angle used in locating a station was 50° 49′, these acute angles being for stations near the Mississippi shore, and at the shallowest water, the angles being 90° in the deep and swift water.

The shortest distance between the pivot and a front signal was 700 feet on station 1, the entire length of this range being about 7,000 feet. The front signals were 2 feet wide, and if the launch should have moved off of range 10 feet it would be indicated by the front signal being half out of line with the pivot signal, and this could be easily noticed, and in fair weather one-fourth width of front signal out of line could be detected; *i. e.*, in fair weather it could be detected if out of range 5 feet at station 1.

The longest distance between the pivot and a front signal was on range 25; the entire length of the range being about 5,400 feet and distance between signals 2,200 feet, $\frac{1}{2\frac{1}{2}}$ *i. e.*, ½ width of signals = 1½ feet, therefore, the launch at station 25 could be located to the nearest 2½ feet, and station 1 to the nearest 10 feet, and at intermediate stations according to their location between station 1 and station 25.

The instruments used consisted of the Price meter No. 8, a break circuit clock, Morse register, relay sounder, seven electric battery cells, transit, and level.

The plant was worked from the United States steam launch No. 7, the meter being suspended from the end of an 11-foot boom projecting over the stern of the launch, and so fixed as to work on either side or behind. On the side and at the rear end of the boom were bolted two pulley wheels over which were run the three-sixteenths-inch steel sash cord (on which the meter was suspended) and the insulated return circuit wire, both wires being paid out side by side and at the same time. The diameter of the reel where the wire was wound was increased by wrapping with leather, so that the wire had more slack than the sash cord, thus relieving the wire of any extra strain.

Attached to the meter rod was a piano wire which ran over a pulley on the end of a 20-foot boom placed over the bow of the launch, thence to a reel, this guy being necessary to hold the meter directly under the end of the after boom, so that the number of feet of sash cord paid out (after the meter left the surface of the water) would be equal to the depth of the meter below the surface.

The details of the field work for a discharge observation are as follows: Tested lead line, whirled meter by hand, and noted number seconds required to come to rest. Chief of party read gauge to nearest 0.01 of a foot. Then crossing river to Mississippi shore noted distance of water's edge. Anchored at first station, leadsman sounded, recorder lowered meter 0.6 of depth, and took the velocity, the meter boom being swung on the starboard side, raised meter out of water, hauled up anchor, took sounding at the half station, then anchored at the next station, continuing in this way until the water became 20 feet deep. Then the rest of the section was sounded without taking any observations for the velocity, each sounding being taken while launch was drifting with current; noted distance of water's edge Arkansas shore. Returned to first station at which no velocity was taken, meter lowered into water and not taken up until remaining stations had been occupied for velocity, the after boom being swung straight behind, and drift had to be very bad indeed to cause any trouble. At this the chief of party would leave the wheel to the leadsman and stand on the starboard side of the engines and give his attention to the position of the launch as held on the station by the engines and the rudder.

By this method the party could do the work, if necessary, with one less man and save one-half hour in time. After the velocities were all taken the gauge was read as before, lead line tested, and meter whirled.

* * * * * * *

The length of an observation for velocity was generally 150 seconds, unless the engineer should not be exactly on range; then the observations would be continued, or in case of whirls or other irregularities it was thought best to lengthen it.

A table was constructed from the meter rating taken at Amelia in October, 1888, from which all velocities were taken out during the season's work.

The constants used were $a = 3.78$, $b = 0.17$, while the values as used in the final computation* were, $a = 3.87$, $b = 0.27$, taken from meter rating No. 3, December 30, 1888, at Helena, Ark. The other ratings taken at Helena were of no value.

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In the final computation the discharge section has been divided into 13 partial sections, each 400 feet in width, except the ones at each end; each even station being at the dividing line of two sections and each odd station in the center of a section.

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Capt. SMITH S. LEACH,
Corps of Engineers, U. S. A.

EXTRACTS FROM REPORT OF MR. WILLIAM GERIG, ASSISTANT ENGINEER, UPON OFFICE REDUCTION OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT HELENA, ARKANSAS, 1888-'89.

MEMPHIS, TENN., *February 20, 1890.*

* * * * * * *

The coefficients to be used in reducing the registrations of the meter to velocity in feet per second were determined by causing the meter to move through still water, over a known distance, at various velocities, the time and number of registrations being noted.

* * * * * * *

The rating observations† were reduced by the method of least squares. * * * In the final reduction the widths were calculated and the soundings plotted on cross-section sheets, as were also the velocities. The total area was divided into partial areas, and these were calculated by counting the squares, and were multiplied by the mean velocities of the partial areas which were taken from the cross-section sheets. The product was the partial discharge, and the sum of the partial discharges gave the total discharge, and this divided by the total area gave the mean velocity The counting of the registrations was done in the field and checked. The results of computation were copied in a tabular form accompanying this report and also into the note books. The gauge readings correspond to the mean time of observation. The gauge was read at the beginning and ending of the day's work. The rise or fall for 24 hours is the difference in the mean gauge reading for that day and the preceding one.

The computation of datum areas has been made in the following manner: The datum was assumed to correspond to the gauge reading of 32.32 feet; the datum width was taken as 4,818 feet, that being the measured width and gauge reading on March 2, 1889. The slope of the banks down to 21 feet on gauge was uniform; also, from 21 to 19 feet, from 19 to 13 feet, and below 13 feet, and the datum areas have been computed by the formula:

$$\text{Datum area} = (32.32 - h)\,\frac{4818 + w}{2} + \text{water area, where } h = \text{gauge and } w = \text{width.}$$

The formula between 21 and 19 feet on gauge becomes—

$$\text{Datum area} = (32.32 - 21.00)\,\frac{4818 + 4700}{2} + (21.00 - h)\,\frac{4700 + w}{2} + \text{water area}$$

$$= 53872 + (21.00 - h)\,\frac{4700 + w}{2} + \text{water area,}$$

in which 4,700 feet is the width for 21-foot stage.

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* See Mr. Gerig's report herewith.

† For date of observations, etc., see Mr. Sturtevant's report herewith.

For stages between 19 and 13 feet—

$$\text{Datum area} = 53872 + (21-19)\frac{4700+3392}{2} + (19-h)\frac{3392+w}{2} + \text{water area}$$

$$= 61964 + (19-h)\frac{3392+w}{2} + \text{water area},$$

in which 3,392 feet is the width at 19-foot stage.

For stages below 13 feet the formula becomes—

$$\text{Datum area} = 61964 + (19-13)\frac{3392+2705}{2} + (13-h)\frac{2705+w}{2} + \text{water area}$$

$$= 80255 + (13-h)\frac{2705+w}{2} + \text{water area},$$

in which 2,705 feet is the width at 13-foot stage.

The mean depth has been obtained by dividing the water area by the width, and the mean datum depth has been obtained by dividing the datum area by the datum width. Maximum depth was taken directly from the notes. Scour or fill has been obtained by taking the difference of the datum areas, scour indicated by the positive sign. The direction of the wind is indicated by dividing the horizon into 12 parts and numbering the parts the same as the hours on a clock dial, XII being upstream and indicating a downstream wind.

The entire work has been checked in various ways and great care has been taken to eliminate all errors of computation.

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Capt. SMITH S. LEACH,
Corps of Engineers, U. S. A.

*Results of discharge observations, Mississippi River, Helena, Ark., 1888–'89.**

Date.		Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
		Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.					
				Water.	Below datum.	Mean.	Mean datum.	Maximum.						
1888.		Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.		
Nov.	28	26.70	−0.50	133,997	160,832	28.3	33.2	75.0	4,732		4.219	565,310	XII—Light	Meter.
	29	25.98	−0.72	129,545	159,796	27.4	33.2	72.0	4,725	−1,036	4.390	568,714	VIII—Very light	Do.
	30	24.95	−1.03	125,124	160,278	26.5	33.2	74.4	4,722	+ 482	4.383	548,408	X—Moderate	Do.
Dec.	1	23.81	−1.14	118,436	158,999	25.1	33.0	72.0	4,715	−1,279	4.381	518,854	XI—Moderate	Do.
	2	22.40	−1.41											
	3	21.12	−1.28	107,901	161,213	22.9	33.5	73.0	4,702	+2,214	4.570	493,081	VIII—Moderate	Do.
	4	19.87	−1.25	98,462	156,970	28.1	32.6	74.0	3,505	−4,243	4.641	456,952	IV—Very light	Do.
	5	18.57	−1.30	92,620	156,011	28.5	32.5	71.0	3,244	− 959	4.773	442,074	VI—Light	Do.
	6	17.29	−1.28	88,600	156,106	28.6	32.5	67.0	3,090	+ 95	4.719	418,138	XII—Moderate	Do.
	7	15.99	−1.30	83,572	155,000	28.5	32.2	68.0	2,938	−1,106	4.402	467,930	IV—Moderate	Do.
	8	14.74	−1.25	81,521	156,859	28.3	32.6	68.5	2,887	+1,859	4.097	333,977	IV—Moderate	Do.
	9	13.60	−1.14											
	10	12.70	−0.90	69,929	150,992	26.1	31.3	61.0	2,680	−5,867	4.063	284,144	XII—Light	Do.
	11	11.82	−0.88	67,645	151,071	25.3	31.4	64.0	2,670	+ 79	3.927	265,627	I—Very light	Do.
	12	11.06	−0.76	67,315	152,780	25.2	31.7	61.2	2,666	+1,709	4.057	273,108	II—Very light	Do.
	13	10.50	−0.56	65,424	152,267	25.5	31.6	62.3	2,565	− 513	4.101	268,752	VII—Moderate	Do.
	14	9.97	−0.53	64,097	152,245	25.6	31.6	62.5	2,505	− 22	3.949	253,139	XII—Very light	Do.
	15	9.50	−0.47										IV—Strong	Do.
	16	9.42	−0.08	61,910	151,482	24.8	31.4	60.2	2,500	− 763	3.931	243,358	VII—Light	Do.
	17	9.35	−0.07	62,485	152,239	25.0	31.6	62.8	2,500	+ 757	3.931	245,623	IX—Light	Do.
	18	9.24	−0.11	62,567	152,607	25.0	31.7	61.0	2,500	+ 368	3.830	239,577	IX—Light	Do.
	19	9.06	−0.17	61,395	151,884	24.7	31.5	60.0	2,490	− 723	3.908	239,947	XI—Light	Do.
	20	8.99	−0.08	61,990	152,631	25.0	31.7	60.0	2,475	+ 747	3.893	241,337	VI—Light	Do.
	21	8.93	−0.06	60,440	151,231	24.5	31.4	60.0	2,473	−1,400	3.915	236,656		
	22	8.95	+0.02	60,155	150,889	24.4	31.3	60.0	2,470	− 342	3.824	229,064	I—Very light	Do.
	23	9.25	+0.30											
	24	9.62	+0.37	61,450	150,401	24.6	31.2	56.0	2,500	− 488	3.928	241,347	IV—Light	Do.
	25	10.25	+0.63	63,730	151,204	24.9	31.4	58.2	2,555	+ 803	3.954	251,951	IV—Very light	Do.
	26	10.96	+0.71	64,828	150,442	25.3	31.2	59.0	2,562	− 762	4.209	272,842	IX—Very strong	Do.
	27	11.44	+0.47	66,284	150,693	25.8	31.3	59.0	2,620	+ 251	4.130	273,787	IX—Moderate	Do.
	28	11.69	+0.25	67,913	151,682	25.4	31.4	60.0	2,680	+ 989	4.133	280,641	XII—Moderate	Do.
	29	11.95	+0.26	69,955	153,024	26.1	31.8	60.0	2,680	+1,342	4.129	288,827	XII—Light	Do.
	30	12.45	+0.50											
	31	13.10	+0.65	71,752	151,702	26.5	31.4	61.0	2,705	−1,322	4.143	297,185	XII—Light	Do.
1889.														
Jan.	1	13.92	+0.82	75,125	152,779	27.0	31.7	63.0	2,785	+1,077	4.233	317,972	XII—Moderate	Do.
	2	14.85	+0.23											
	3	15.34	+0.49	80,594	154,035	28.0	31.9	63.7	2,888	+1,256	4.240	341.753	II—Light	Do.
	4	15.62	+0.28											

5	15.60	—0.02	79,631	152,340	27.1	31.6	64.0	2,938	—1,695	4.354	346,734	XI—Light	Do.
6	15.25	—0.35											Do.
7	14.86	—0.39	77,343	152,307	26.5	31.6	63.5	2,888	— 33	4.227	326,859	VI—Light	Do.
8	14.48	—0.38	76,572	152,670	26.7	31.7	63.2	2,862	+ 363	4.172	319,416	Fog	Do.
9	14.49	—0.01	77,331	153,398	27.0	31.8	63.7	2,862	+ 728	4.292	331,911	VIII—Strong	Do.
10	14.74	+0.25	77,153	152,446	26.9	31.6	63.0	2,873	— 952	4.284	326,684	VII—Very light	Do.
11	15.39	+0.65	80,059	153,379	27.5	31.8	62.8	2,908	+ 933	4.472	358,036	Calm	Do.
12	16.40	+1.01	84,127	154,430	28.2	32.0	65.3	2,989	+ 1,051	4.483	377,117	IV—Light	Do.
13	18.00	+1.60											
14	19.65	+1.65	94,574	153,909	27.9	31.9	67.0	3,394	— 521	4.778	450,361	XII—Light	Do.
15	21.95	+2.30					71.2					IV—Moderate	Do.
16	24.32	+2.37	127,275	165,323	27.1	34.4	75.0	4,700	+11,414	4.741	603,411	VII—Moderate	Do.
17	25.56	+1.23	131,624	163,876	27.8	34.0	78.0	4,724	— 1,447	4.781	629,580	XII—Moderate	Do.
18	26.36	+0.80	133,914	162,355	28.1	33.7	78.0	4,734	— 1,521	4.630	619,969		
19	27.03	+0.66	137,962	163,248	29.1	33.9	78.5	4,742	+ 893	4.635	639,500	II—Light	Do.
20	27.98	+0.95											
21	28.65	+0.67	141,163	158,726	29.6	33.0	77.5	4,766	— 4,522	4.650	656,457	Calm	Do.
22	29.50	+0.85	145,823	159,028	30.5	33.1	79.0	4,777	+ 302	4.700	685,324	VI—Light	Do.
23	30.40	+0.89	151,100	160,313	31.6	33.2	80.0	4,779	+ 1,285	5.016	757,926	I—Light	Do.
24	31.15	+0.75	161,333	166,931	33.7	34.7	80.0	4,782	+ 6,618	4.797	773,807	II—light	Do.
25	31.35	+0.20										I—Fog	Do.
26	31.25	—0.10										Fog	Do.
27	30.85	—0.40	149,397	156,383	31.2	32.5	79.5	4,787	—10,548	4.658	695,785	VIII—Strong	Do.
28	30.10	—0.75	150,039	160,687	31.4	33.3	79.5	4,775	+ 4,304	4.696	704,632	X—Very strong	Do.
29	29.14	—0.96	142,318	157,556	29.9	32.7	79.5	4,766	— 3,131	4.697	668,387	IX—Light	Do.
30	28.06	—1.08	134,860	155,250	28.4	32.3	77.0	4,755	— 2,306	4.596	619,811	V—Moderate	Do.
31	27.25	—0.80	132,382	156,595	27.0	32.6	75.0	4,743	+ 1,345	4.553	602,791	I—Very light	Do.
Feb. 1	26.86	—0.39	131,322	157,407	27.7	32.7	75.0	4,737	+ 812	4.503	591,403	I—Very light	Do.
2	26.88	+0.02	133,727	159,701	28.2	33.2	77.0	4,740	+ 2,294	4.468	597,532	VII—Moderate	Do.
3	27.25	+0.37											
4	27.79	+0.54	136,612	158,273	28.7	32.7	76.0	4,756	— 1,428	4.709	643,403	VI—Light	Do.
5	28.44	+0.64	139,858	158,445	29.4	32.8	75.2	4,763	+ 172	4.581	640,760	X—Strong	Do.
6	29.01	+0.57	140,845	156,699	29.5	32.6	75.5	4,776	— 1,746	4.674	657,797	XII—Strong	Do.
7	29.33	+0.31	142,372	156,717	29.8	32.6	77.0	4,777	+ 18	4.713	671,028	VI—Moderate	Do.
8	29.28	—0.05	144,432	159,029	30.2	33.1	77.2	4,780	+ 2,312	4.750	684,051	VII—Light	Do.
9	28.95	—0.33	142,580	158,749	29.8	32.9	76.0	4,778	— 280	4.600	655,905	XI—Light	Do.
10	28.08	+0.87											
11	27.03	—1.05	134,209	159,567	28.2	33.2	76.0	4,769	+ 818	4.414	592,456	IX—Moderate	Do.
12	25.62	—1.41	128,352	160,331	27.6	33.3	75.0	4,728	+ 764	4.334	556,252	IX—Light	Do.
13	23.90	—1.72	116,969	157,078	24.8	32.6	75.0	4,714	—3,233	4.417	516,585	VII—Strong	Do.
14	22.06	—1.83										Heavy fog	Do.
15	20.13	—1.93										Heavy fog	Do.
16	18.60	—1.53	89,396	152,699	27.1	31.7	67.0	3,293	—4,399	4.354	389,193	VI—Moderate	Do.
17	17.18	—1.42											
18	16.19	—0.99	83,028	154,042	27.1	32.0	65.0	3,061	+1,343	4.261	353,797	XI—Strong	Do.
19	15.18	—1.01	80,428	154,554	26.9	32.0	64.0	2,984	+ 512	4.205	338,195	XI—Moderate	Do.
20	14.51	—0.67	76,823	152,859	26.6	31.7	62.3	2,883	—1,695	4.187	321,689	IV—Light	Do.
21	14.69	+0.17	77,802	153,289	27.0	31.8	64.0	2,883	+ 430	4.391	341,645	V—Very light	Do.
22	16.60	+1.91	83,215	152,921	27.1	31.7	66.0	3,073	— 368	4.601	382,856	VII—Light	Do.

* From reduction at office of Second District Engineer.

Results of discharge observations, Mississippi River, Helena, Ark., 1888–'89—Continued.

Date.		Gauge. Reading.	Gauge. Rise or fall in the preceding 24 hours.	Cross section of discharge. Area. Water.	Cross section of discharge. Area. Below datum.	Cross section of discharge. Depth. Mean.	Cross section of discharge. Depth. Mean datum.	Cross section of discharge. Depth. Maximum.	Cross section of discharge. Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	Method.
	1889.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.		
Feb.	2	20.54	+3.94	*100,408	156,236	25.8	32.5	70.5	3,897	+3,315	*4.951	*497,161	XII—Strong	Meter.
	24	23.85	+3.31											
	25	25.96	+2.11	129,085	159,427	27.3	33.2	74.2	4,731	+3,191	4.730	610,507	XI—Moderate	Do.
	26	27.93	+1.96	140,113	161,130	29.4	33.4	75.6	4,757	+1,703	4.795	671,820	VI—Very light	Do.
	27	29.54	+1.61	147,967	161,308	30.9	33.5	77.0	4,780	+ 178	4.892	723,872	VI—Light	Do.
	28	30.95	+1.41	155,742	162,332	32.4	33.7	79.5	4,802	+1,024	4.856	256,200	Fog	Do.
Mar.	1	31.72	+0.77					79.0	4,809				Fog	Do.
	2	32.32	+0.60	164,099	164,099	34.1	34.1	81.2	4,818	+1,767	4.873	799,657	XII—Moderate	Do.
	3	32.30	—0.02											
	4	32.09	—0.21	163,218	164,301	33.9	34.2	80.5	4,810	+ 202	4.569	745,773	XII—Very light	Do.
	5	31.65	—0.44	160,826	164,049	33.5	34.1	80.0	4,804	— 252	4.606	740,737	XI—Moderate	Do.
	6	31.14	—0.51	154,837	160,511	32.3	33.3	78.0	4,800	—3,538	4.562	706,082	VIII—Light	Do.
	7	30.75	—0.39	154,370	161,912	32.2	33.6	78.0	4,790	+1,401	4.583	707,517	XI—Light	Do.
	8	30.41	—0.34	151,528	160,699	31.7	33.3	78.0	4,785	—1,213	4.474	677,952	X—Moderate	Do.
	9	30.26	—0.15	150,585	160,475	31.5	33.3	78.0	4,784	— 224	4.452	670,488	XI—Strong	Do.
	10	29.93	—0.33											
	11	29.46	—0.47	144,604	158,304	30.3	32.9	76.3	4,779	—2,171	4.388	634,548	VI—Very light	Do.
	12	28.75	—0.71	141,278	158,382	29.7	32.9	75.5	4,764	+ 78	4.392	620,471	VI.—Very light	Do.
	13	27.94	—0.81	137,461	158,424	28.8	32.9	75.0	4,754	+ 42	4.377	601,689	I—Light	Do.
	14	27.02	—0.92	132,030	157,388	27.8	32.7	75.0	4,751	—1,036	4.430	584,788	V—Very light	Do.
	15	26.12	—0.89	127,405	156,995	26.9	32.6	73.5	4,735	— 393	4.363	555,891		
	16	25.52	—0.60	124,891	157,351	26.4	32.7	72.0	4,729	+ 356	4.343	542,347	IX—Light	Do.
	17	24.83	—0.69											
	18	24.43	—0.40	118,029	155,568	25.0	32.2	72.0	4,723	—1,783	4.428	522,693	VI—Light	Do.
	19	24.05	—0.38	117,766	157,210	25.0	32.7	71.0	4,721	+1,642	4.355	512,825	XII—Strong	Do.
	20	23.55	—0.50	114,676	156,482	24.3	32.6	70.5	4,716	— 728	4.403	504,617	XII—Light	Do.
	21	22.90	—0.65	111,118	156,009	23.6	32.5	72.0	4,713	— 473	4.271	474,499	I—Light	Do.
	22	22.30	—0.60	108,466	156,211	23.0	32.5	69.5	4,712	+ 202	4.239	459,830	II—Moderate	Do.
	23	21.81	—0.49	105,845	155,884	22.5	32.4	68.0	4,708	— 327	4.342	459,589	III—Light	Do.
	24	21.50	—0.31											
	25	21.79	+0.29	105,570	155,701	22.4	32.4	68.5	4,708	— 183	4.414	466,027	XII—Light	Do.
	26	22.60	+0.80	112,424	158,749	23.9	32.9	70.5	4,714	+3,048	4.440	499,114	XI—Very light	Do.
	27	23.79	+1.19	117,662	158,346	24.9	32.7	71.0	4,721	— 403	4.402	517,928	X—Light	Do.
	28	24.83	+1.04	123,032	158,793	26.0	32.9	72.0	4,731	+ 447	4.449	547,395	XII—Light	Do.
	†29	25.42	+0.59										V—Moderate	Do.
	†30	25.45	+0.03											
	†31	25.28	—0.17											
Apr.	1	25.23	—0.05	125,675	159,506	26.5	33.2	74.0	4,732	+ 713	4.419	555,337	XI—Moderate	Do.
	2	25.02	—0.21											

Apr. 3	24.51	−0.51	120,930	158,180	25.6	32.7	71.8	4,721	−1,326*	4.284	518,096	X—Light	Metor.
4	24.02	−0.49											
5	23.85	−0.67	115,946	158,692	24.6	32.9	72.8	4,713	+ 512	4.344	503,592	XI—Very light	Do.
6	22.69	−0.65	114,103	159,961	24.2	33.3	72.0	4,711	+1,269	4.285	488,943	XII—Strong	Do.
7	22.23	−0.46											
8	21.95	−0.28	110,423	159,815	23.5	33.2	72.0	4,708	− 146	4.239	468,049	X—Very light	Do.
9	21.90	−0.05	110,777	160,402	23.5	33.3	72.5	4,707	+ 587	4.338	480,477	VI—Light	Do.
10	21.82	−0.08	111,022	161,028	23.6	33.4	73.0	4,707	+ 626	4.317	479,300	VIII—Very light	Do.
11	21.65	−0.17	110,622	161,438	23.5	33.5	73.5	4,707	+ 410	4.273	472,722	VII—Light	Do.
12	21.20	−0.45										Very strong	Do.
13	20.84	−0.36	101,798	156,858	26.8	32.6	72.5	3,895	−5,060	4.347	442,536	XI—Moderate	Do.
14	20.23	−0.61											
15	19.79	−0.44	98,330	157,240	28.2	32.7	70.0	3,495	+ 882	4.319	424,637	XII—Light	Do.
16	19.48	−0.31	95,727	155,729	28.2	32.4	69.1	3,393	−1,511	4.352	416,484	I—Very light	Do.
17	19.16	−0.32	94,389	155,685	27.9	32.4	70.0	3,392	− 44	4.445	419,562	VII—Very light	Do.
18	18.82	−0.34	92,040	154,598	27.5	32.0	69.0	3,341	−1,092	4.311	396,770	VI—Strong	Do.
19	18.49	−0.33	88,937	152,605	27.0	31.7	67.5	3,291	−1,988	4.442	395,048	VI—Strong	Do.
20	18.40	−0.09	88,657	152,626	26.9	31.7	66.7	3,291	+ 21	4.346	385,319	X—Very light	Do.
21	18.80	+0.40											
22	19.45	+0.65	94,082	154,226	27.7	32.0	70.0	3,393	+1,600	4.486	423,069	I—Moderate	Do.
23	20.23	+0.78	96,714	153,818	26.2	31.9	70.3	3,694	− 408	4.413	426,760	XI—Very light	Do.
24	20.85	+0.62	102,239	156,817	21.7	32.6	69.8	4,708	+2,999	4.445	454,408	XII—Light	Do.
25	21.40	+0.55	105,466	157,478	22.4	32.8	71.0	4,708	+ 661	4.404	464,437	XII—Light	Do.
26	21.91	+0.51	108,068	157,648	22.9	32.8	69.2	4,712	+ 170	4.401	475,572	XI—Very light	Do.
27	22.67	+0.76	110,920	156,888	23.6	32.6	70.0	4,714	− 760	4.478	496,670	X—Moderate	Do.
28	23.35	+0.68											
29	23.57	+0.22	114,358	156,065	24.3	32.5	71.0	4,715	− 823	4.455	509,474	X—Light	Do.
30	23.22	−0.35	113,752	157,122	24.1	32.7	70.2	4,714	+1,057	4.410	501,645	XI—Moderate	Do.
May 1	22.27	−0.95	109,808	157,676	23.3	32.8	70.0	4,708	+ 554	4.267	468,497	X—Moderate	Do.
2	20.84	−1.43	102,363	156,987	21.9	32.7	68.5	4,702	− 689	4.273	437,446	XI—Moderate	Do.

* For February 23 the note book gives these additional results for the chute: Area 4.002, mean velocity 1.497, discharge 5,991.
† Launch pump broken.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE, MISSISSIPPI RIVER COMMISSION, OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT WARRENTON, MISSISSIPPI, 1889.

The discharge section was located by Mr. John Ewens, assistant engineer, January 31, 1889, and the discharge observations were made by Mr. Thomas Dailey.

A sketch received, with copy of field notes, shows the section to have been 2,800 feet downstream from the landing at Warrenton, and apparently about 200 feet above the upper discharge section of 1885 and oblique to it. A local gauge was established, and is shown on the left bank at the mouth of a bayou about 1,200 feet upstream from the discharge section, and is stated to have been set at precisely the same reading as the gauge at Vicksburg, February 11, 1889, at 11 a. m., viz, 32.85 feet.

Mr. Ewens reports, referring to this local gauge, "A temporary bench was established from this for future reference. There was no data at hand for direct connection with survey Mississippi River."

Datum line in the tabulation is taken at 33.50 feet on the local gauge. Datum width is 3,470 feet. The datum areas were computed from readings of this gauge, except for May 29 and 31, when it was disturbed and the Vicksburg gauge readings were used. Up to that time the readings on both gauges agreed closely. The zero of the Vicksburg gauge is 66.04 feet above the Cairo datum plane, survey Mississippi River.

The sounding and velocity-stations were coincident, and were located by means of fixed signals on the left bank. The distance between stations was mainly about 150 feet. At stations nearest the right bank velocity observations were omitted for a large number of days, the number of omitted stations varying from 1 to 6, increasing as the river fell. It is stated that owing to low water the launch could not reach the stations. The soundings at the omitted stations were from 1 to 16 feet.

The velocities adopted for these stations were obtained by using as a correction the mean difference between each station and the preceding station, derived from days on which both stations were observed; but at stations 23 and 24 no velocities had been observed, and the mean from curves of March 12 and 14 produced were adopted, velocities at stations 22 or 21 having been observed only on those dates.

The Price current meter No. 22 was used in measuring all velocities at this station during the season; the notes of two sets of rating observations were received, and the results derived from reduction in this office by the usual method are given in the subjoined table:

Designation of meter.	Date and locality of rating observations.	No. of observations.	a	b	Mean error of observation.	Mean error of a	Mean error of b
Price meter No. 22.	February 26, 1889, not stated.	*8	4.0226	+0.2911	±0.127	±0.064	±0.088
	April 7, 1889, Centennial Lake	*8	3.8934	+0.31698	±0.059	±0.30	±0.046

* In running water.

The above results were combined, giving weight to the values of a and b inversely as the squares of their mean errors in the two series and the resulting equation, $y = 3.917\,x + 0.3114$, was used in computing all the discharges.

The time meter was run at each velocity station varied from 1 to 6 minutes, but was usually 5 minutes.

The observer reports that on April 20 the vane was broken off of the meter, and when soldered on again it was not exactly in line with the meter wheel; on May 8 a re-rating of the meter was made, the notes of which have not been received. The ratings of February 26 and April 7 only were used, the district engineer in charge of the field work having so recommended, since the rate of the meter was believed not to have been changed and the observations for a re-rating were unskillfully made.

In computing the discharges of this series, since the sounding and velocity stations were coincident, the mean of the velocities observed or adopted at two consecutive stations was taken and applied to the area between them. To make this result agree more closely with that which would have been obtained by using the prismoidal formula, an approximate correction was computed and applied for each day; this correction varied from 0 to + 240 cubic feet.

The other quantities tabulated have been found in the usual manner as described in previous office reports.

A plate has been prepared showing the mean velocities, areas, and discharges plotted to gauge heights and the gauge readings and datum areas in chronological order, also two cross-section profiles of the river.

OFFICE SECRETARY MISSISSIPPI RIVER COMMISSION,
September, 1890.

Results of discharge observations, Mississippi River, Warrenton, Miss., 1889.

Date.	Vicksburg gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Feet.			
Mar. 12*	33.53	− 0.1	163,510	163,510	47.1	47.1	88.8	3,470				East. Light		24
13	33.35	− 0.1												
14*	32.95	− 0.4	149,868	151,253	43.4	43.6	80.7	3,456	− 12,257			Calm		24
15	32.42	− 0.6	145,577	148,962	42.3	42.9	78.6	3,439	− 2,291	4.857	707,060		20	24
16	31.90	− 0.5	§145,870	151,038	42.6	43.5	79.4	3,421	+ 2,076	4.804	700,807		20	24
17	31.20	− 0.7												
18	30.65	− 0.6												
19	30.63	− 0.6												
20	29.25	− 0.8	138,304	152,163	41.2	43.9	77.0	3,357	+ 1,125	4.785	661,771	Calm	20	24
21	28.60	− 0.6	133,277	149,526	39.9	43.1	76.1	3,343	− 2,637	4.622	616,030		19	24
22	27.95	− 0.6	130,564	148,910	39.3	42.9	74.9	3,325	− 616	4.630	604,543		19	23
23	27.40	− 0.6	130,949	151,333	39.7	43.6	74.0	3,302	+ 2,423	4.527	592,812	Foggy	19	23
24	26.90	− 0.5												
25	26.43	− 0.5	128,007	151,692	39.1	43.7	72.6	3,278	+ 259					23
26	25.92	− 0.5	127,329	152,550	39.0	44.0	72.9	3,267	+ 867					23
27	25.58	− 0.3	123,757	150,160	38.0	43.3	71.2	3,257	− 2,399	4.280	529,720		19	23
28	25.55	0.0	124,083	150,908	38.1	43.5	71.3	3,253	+ 748	4.363	541,356		19	23
29	26.17	+ 0.6	126,362	151,345	38.7	43.6	71.3	3,264	+ 437	4.703	594,288		19	23
30	27.35	+ 1.2	132,225	153,577	40.2	44.3	72.5	3,287	+ 2,232	4.771	630,784		19	23
31	28.43	+ 1.0												
Apr. 1	29.37	+ 1.0	141,396	155,788	42.2	44.9	74.3	3,351	+ 2,211	5.013	708,870		20	23
2	29.90	+ 0.5	142,151	154,787	42.8	44.6	75.3	3,360	− 1,001	5.032	715,233		20	24
3	30.15	+ 0.3	140,454	152,079	41.7	43.8	74.8	3,368	− 2,708	4.983	699,851		20	24
4	30.30	+ 0.1	139,899	150,911	41.5	43.5	75.8	3,370	− 1,168	4.931	689,892		20	24
5	30.23	− 0.1	140,870	152,154	41.8	43.8	75.7	3,369	+ 1,243	4.932	694,830		20	24
6	30.05	− 0.2	141,725	153,522	42.1	44.2	75.7	3,369	+ 1,368	4.939	699,958	Strong	20	24
7	29.75	− 0.2												
8†	29.40	− 0.4	139,589	153,512	41.6	44.2	75.4	3,355	− 10	4.783	667,722	Calm	20	23
9	28.98	− 0.4												
10	28.57	− 0.4	137,010	153,682	41.1	44.3	74.7	3,335	+ 170	4.746	650,209	Calm	20	23
11‡	28.18	− 0.4	135,520	153,187	40.8	44.1	73.8	3,325	− 495	4.655	630,778		19	23
12	27.88	− 0.3	133,368	152,437	40.2	43.9	73.6	3,316	− 750	4.667	622,393	Light	19	23
13	27.55	− 0.3	133,325	154,526	40.4	44.5	74.8	3,304	+ 2,089	4.629	617,117	Calm	19	23
14	27.58	0.0												

* Drift prevented completion of velocity observations.
† Some drift.
‡ Conditions favorable.
§ Observer states that soundings of this date are more satisfactory than any taken previously.
NOTE.—These observations were taken with meter at six-tenths depth as the mean velocity at each velocity station.

Results of discharge observations, Mississippi River, at Warrenton, Miss., 1889—Continued.

Date.	Vicksburg gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*			
Apr. 15	27.80	− 0.3	133,543	154,444	40.5	44.5	74.8	3,294	− 82	4.551	607,797	Calm	19	23
16	26.80	− 0.5	132,511	155,748	40.3	44.9	74.8	3,285	+ 1,304	4.519	*598,762	Calm	17	23
17	26.20	− 0.6	130,256	154,616	39.7	44.6	74.3	3,278	− 1,132	4.575	595,877	Calm	19	23
18	25.70	− 0.5	127,988	154,251	39.2	44.5	73.3	3,264	− 365	4.416	565,155	Light	19	23
19	25.12	− 0.6	125,134	153,089	38.5	44.1	72.7	3,250	− 1,162	4.443	555,936	Light	19	23
20	24.60	− 0.5	123,291	153,124	38.1	44.1	71.6	3,234	+ 35	4.312	531,595	Calm	19	23
21	24.02	− 0.6												
22	23.50	− 0.5	118,772	152,237	36.9	43.9	70.5	3,223	− 887	4.393	521,796	Calm	19	22
23	23.18	− 0.3	117,214	151,930	36.4	43.8	69.6	3,219	− 307	4.317	505,979	Calm	18	22
24	23.05	− 0.2	116,215	151,441	36.2	43.6	69.6	†3,208	− 489	4.408	512,307	Calm	16	22
25	23.12	+ 0.1	115,586	150,479	36.0	43.4	69.4	†3,208	− 962	4.440	513,159	Light	18	22
26	23.25	+ 0.1	116,105	150,345	36.2	43.3	69.6	†3,211	− 184	4.359	506,124	Calm	18	22
27	23.58	+ 0.4	118,882	152,738	36.9	44.0	70.7	3,221	+ 2,393	4.437	527,509		18	
28	24.00	+ 0.4												
29	24.60	+ 0.6	122,387	152,613	37.9	44.0	71.4	3,232	− 125			Very strong		22
30	25.25	+ 0.6	124,586	152,881	38.5	44.0	71.7	3,239	+ 218	4.675	582,425	Calm	19	22
May 1	25.95	+ 0.7												
2	26.10	+ 0.1												
3	25.80	− 0.3	127,059	152,973	39.0	44.1	72.6	3,261	+ 142	4.562	579,654	Light	19	23
4	25.15	− 0.6	125,274	153,213	38.6	44.2	72.0	3,246	+ 240	4.575	573,102		19	23
5	24.25	− 0.9												
6	23.20	− 1.0	116,569	150,860	36.2	43.5	69.5	3,221	− 2,853	4.409	513,951		18	22
7	21.98	− 1.2	113,447	151,320	35.6	43.6	68.2	3,186	+ 460	4.310	488,962		18	22
8	20.72	− 1.3												
9	19.40	− 1.3	105,051	151,066	33.7	43.5	66.1	3,118	− 254	4.134	434,268		17	21
10	18.35	− 1.0	100,840	149,794	32.8	43.2	60.5	3,079	− 1,272	4.058	409,180		16	21
11	17.55	− 0.8	98,136	150,202	31.9	43.3	59.5	3,071	+ 408	3.980	390,553		16	21
12	16.78	− 0.8												
13	16.20	− 0.6	94,368	150,092	31.4	43.8	58.8	3,002	− 110	3.945	372,264		15	21
14	15.70	− 0.5	91,910	149,339	30.7	43.0	58.4	2,990	− 753	4.002	367,828		15	21
15	15.15	− 0.5	90,799	149,209	30.5	43.0	57.4	2,977	− 130	3.949	358,578	Calm	15	21
16	14.95	− 0.2	89,620	148,771	30.1	42.9	57.5	2,977	− 438	3.997	358,253	Strong	15	21
17	14.90	− 0.1	88,764	148,380	29.8	42.8	57.2	2,975	− 391	4.021	356,937	Calm	15	21
18	14.90	0.0	88,907	148,523	29.9	42.8	57.5	2,975	+ 143	4.019	357,311	Calm	15	21
19	14.75	− 0.1												
20	14.40	− 0.4	85,412	146,490	28.8	42.2	55.0	2,966	− 2,083	4.088	344,853	Calm	15	20
21	13.80	− 0.6	84,811	147,085	28.7	42.4	56.3	2,950	+ 595	4.018	340,807		15	20
22	13.45	− 0.4	83,071	147,121	28.3	42.4	55.6	2,935	+ 36	3.926	326,157		15	20
23	13.25	− 0.2	82,234	146,860	28.0	42.3	54.7	2,935	− 261	3.941	324,097		14	20

24	13.20	0.0	81,580	146,159	27.9	42.1	54.5	2,924	− 701	3,974	324,238		14	19
25	13.20	0.0	81.709	146,288	27.9	42.2	54.4	2,924	+ 129	4,053	331,180		14	19
26	13.10	−0.1												
27	13.30	+0.2	81,258	145.807	27.8	42.0	54.4	2,921	− 481	4,019	326,591		14	19
28	13.92	+0.6	84,127	147,174	28.5	42.4	54.8	2,947	+1,367	4,043	340,096		15	20
29	15.15	+1.3	86,596	145,747	29.1	42.0	55.4	2,977	−1,427	4,378	379,102		15	20
30	17.57	+2.4												
31	18.83	+1.3	95,331	143,471	30.8	41.3	59.3	3,098	−2,276	4,435	422,761		16	19

* Observer states these velocity observations are unreliable on account of register not working well, caused on 16th by loose spool in register, and on the 24th by wire broken inside of insulation.

† Width doubtful, probably 10 feet more than recorded.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE, MISSISSIPPI RIVER COMMISSION, OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT RED RIVER LANDING, OLD RIVER BELOW TURNBULL ISLAND, AND ATCHAFALAYA RIVER AT SIMMSPORT, 1889.

The observations were made under direction of the fourth district engineer by Mr. J. F. Coleman.

The location of the Red River Landing discharge section was the same as that of 1884-'85, which is 100 feet below the section used in 1881-'82.

The sounding and velocity stations were coincident, and were located by means of fixed signals on shore. The distance between stations varied from 80 to 172 feet, but across the greater part of the river was about 170 feet.

On and after January 27 velocity stations were omitted at every other station over a large part of the river, and sometimes at two adjacent stations. Velocities for these omitted stations were interpolated for the computation from the nearest stations at which velocities had been observed.

On May 13 and 15 an upstream eddy is noted at first station from the right bank, and since the velocity is not afterwards recorded at this station, it is assumed as zero in the computation of discharge on and after May 13.

The length of time that the velocity was observed at a station varied from 1 to 6 minutes, but was generally 5 minutes.

The gauge (Red River Landing) was read at 8 a. m. and 4 p. m., and the mean (except in three cases where a single reading is taken) is given in the tabulation and was used in computing datum areas.

The datum line is taken at 48.50 feet on the gauge, that being the high-water reading of 1882, and is the same datum as used in the two other series of discharge observations at this station.

Datum widths and corresponding gauge heights used in computing datum areas are: Datum width, 3,918 feet at 48.50 feet, 3,888 feet at 34 feet, and 3,800 feet at 24 feet.

The Price current meter No. 23 was used throughout the season at this section; also in the Old and Atchafalaya rivers. The notes of only one set of rating observations have been received, and the results derived from reduction in this office by the usual method are as follows, and have been used in computing the discharges at the three stations:

Designation of meter.	Date and locality of rating observations.	No. of observations.	a	b	Mean error of observation.	Mean error of a	Mean error of b
Price meter No. 23...	February 26, 1889....	*14	4.1091	+ 0.298	±0.089	±0.034	±0.047

* In running water.

The observer frequently tested the action of the meter by noting the number of registrations it would make after turning the wheel briskly with the hand, and states that the rate thus indicated was practically constant.

The computations of the discharges were made in the same manner as for Warrenton, described on page 3512; the corrections applied to the computed results are:

Mississippi River, 0 to + 1,090 cubic feet.

Old River, 0 to + 90 cubic feet.

Atchafalaya River, 0 to + 400 cubic feet, except 1 day 900 cubic feet.

The discharge section in Old River is about 1,500 feet below the foot of Turnbull Island and about 500 feet above the discharge section of 1884-'85.

The sounding and velocity stations were coincident and were located by means of fixed signals on shore; the distance between stations varied from 60 to 90 feet. Datum line is taken at 33.85 feet on the Red River Landing gauge. The methods of reduction are the same as those used for the Red River Landing section. The length of time velocity was observed at each station varied from 2 to 5 minutes, but was generally 2 minutes.

The discharge section in the Atchafalaya River is at Simmsport. The velocity and sounding stations were coincident and were located by means of fixed signals on shore; the distance between stations varied from 64 to 139 feet. Velocity observations at the first and last stations were omitted on several days; probable values for these, derived from observations of other days, were adopted in the computation. The notes state that when the velocity of the river is low and there is much wind, as was the case January 21, that the launch was almost unmanageable, and in consequence the observations for such days were not very accurate; throughout the sea

son it is noted several times that owing to strong upstream wind no observations could be made.

The length of time velocity was observed at each station varied from 1 to 5 minutes, but was generally 2 minutes.

The methods of reduction are the same as those used for the Red River Landing section. The Simmsport gauge was read apparently at the time of discharge observations; these readings are given in the tabulation and are used in computing datum areas. The zero of this gauge is reported to be 24.17 feet above the Cairo datum plane, survey Mississippi River, but is to be again connected with that datum.

The datum line is taken at 32.30 feet on the Simmesport gauge, and datum width at 885 feet. In computing datum areas from April 16 the width for 27.40 feet on the gauge is taken at 800 feet.

The results of the Red River Landing section are shown on a plate arranged in the usual way, the mean velocities, areas, and discharges plotted to gauge heights, and the datum areas and gauge readings in chronological order; also two cross-section profiles of the river.

OFFICE SECRETARY MISSISSIPPI RIVER COMMISSION,

September, 1890.

Results of discharge observations, Mississippi River, Red River Landing, La., 1889.

Date.		Red River Landing gauge. Reading.	Red River Landing gauge. Rise or fall in the preceding 24 hours.	Cross section of discharge. Area. Water.	Area. Below datum.	Depth. Mean.	Depth. Mean datum.	Depth. Maximum.	Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
1889.		Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet			
Jan.	10*	19.50	+0.1	112,152	224,241	29.7	57.2	50.2	3,780	....	3.843	430,945	Up & across; strong	24	24
	11	19.35	—0.1	111,927	224,585	29.6	57.3	49.5	3,780	+ 344	3.949	442,049	....	†16	18
	12	19.15	—0.2	113,798	227,201	30.1	58.0	53.0	3,775	+2,616	3.786	430,808	....	24	24
	14	18.92	—0.1	114,142	228,404	30.3	58.3	52.6	3,770	+1,203	3.850	439,403	....	24	24
	16	19.90	+0.7	116,410	226,983	30.8	57.9	52.4	3,780	—1,421	3.707	‡431,575	....	23	23
	18§	22.30	+1.2	130,370	231,856	34.4	59.2	56.0	3,790	+4,873	4.147	540,690	....	24	24
	19§	23.60	+1.3	136,683	233,236	36.0	59.5	58.0	3,795	+1,380	4.380	598,716	Strong..........	25	
	22	27.50	+1.2	152,576	234,228	39.9	59.8	62.5	3,822	+ 992	....	....	Light..........	....	
	23	28.40	+1.1	157,603	235,802	41.2	60.2	66.0	3,828	+1,574	....	....	....	....	
	25	30.30	+0.8	163,640	234,533	42.6	59.9	68.2	3,841	—1,269	....	....	....	....	
	27	31.84	+0.7	170,106	235,059	44.2	60.0	66.8	3,852	+ 526	4.686	797,156	Strong..........	15	
	28‖	32.30	+0.4	171,644	234,821	44.5	59.9	68.1	3,857	— 238	4.762	817,300	....do..........	15	
	29	32.60	+0.3	172,445	234,466	44.6	59.8	66.8	3,865	— 355	4.774	823,300	....	15	
	30¶	32.82	+0.2	176,066	237,237	45.5	60.6	70.2	3,870	+2,771	4.693	826,200	Strong..........	15	
Feb.	1	33.20	+0.2	175,033	234,733	45.1	59.9	69.8	3,878	—2,504	4.355	762,249	....	15	
	2	33.14	0.0	178,902	238,834	46.2	61.0	70.2	3,875	+4,101	4.522	808,958	....	15	
	6	33.00	0.0	173,293	233,768	44.7	59.7	73.8	3,874	—5,066	4.496	779,134	Strong..........	15	
	7	33.11	+0.1	170,609	230,658	44.0	58.9	72.8	3,875	—3,110	4.332	739,036	....	15	
	9	33.30	+0.1	175,183	234,495	45.2	59.9	69.6	3,878	+3,837	4.313	755,638	Strong..........	15	25
	11	33.58	+0.1	176,850	235,076	45.6	60.0	69.7	3,882	+ 581	....	....	....	....	
	13	33.52	—0.1	177,786	236,245	45.8	60.3	70.4	3,881	+1,169	4.300	764,452	Up; strong..........	15	
	14**	33.38	—0.1	176,443	235,445	45.5	60.1	70.5	3,879	— 800	4.337	765,813	....	15	
	16**	32.81	—0.4	176,734	237,941	45.7	60.7	70.1	3,865	+2,496	4.231	747,748	....	15	
	18	31.62	—0.6	174,709	240,515	45.3	61.4	69.8	3,853	+2,574	4.018	702,065	N.; very strong..	15	
	20	29.88	—0.9	166,244	238,756	43.3	60.9	66.5	3,839	—1,759	3.940	655,080	Very strong......	15	
	21	28.96	—0.9	161,874	237,927	42.2	60.7	65.4	3,834	— 829	3.803	615,582	....	15	
	23	26.96	—1.0	155,077	238,800	40.6	60.9	64.9	3,819	+ 873	3.597	557,782	....	15	
	25	25.32	—0.6	148,202	238,214	38.9	60.8	63.1	3,812	— 586	3.822	566,490	....	15	
	28	26.62	+0.9	152,192	237,229	39.8	60.5	64.1	3,820	— 985	3.992	607,552	....	15	
Mar.	4	31.15	+0.9	170,109	237,730	44.2	60.7	68.6	3,850	+ 501	4.127	702,082	Strong..........	15	
	5	31.82	+0.7	173,660	238,699	45.0	60.9	69.8	3,860	+ 969	4.137	718,460	....do..........	15	
	6††	32.32	+0.5	176,145	239,250	45.6	61.1	70.5	3,863	+ 551	4.246	747,891	....	15	
	8	33.12	+0.4	178,906	238,919	46.1	61.0	70.7	3,877	— 331	4.259	762,043	....	14	
	9	33.45	+0.3	181,260	239,989	46.8	61.3	71.8	3,877	+1,070	4.157	753,572	Strong..........	15	
	13††	34.00	0.0	183,704	240,298	47.2	61.3	72.4	3,888	+ 309	4.346	798,353	....	15	
	14††	33.94	0.0	180,518	237,345	46.4	60.6	72.3	3,888	—2,953	4.224	762,477	....	15	
	19	32.52	—0.5	173,211	235,540	44.8	60.1	68.9	3,862	—1,805	4.127	714,841	Strong..........	15	
	21	31.54	—0.4	172,384	238,497	44.8	60.9	68.3	3,851	+2,957	3.969	687,651	....	15	

	23	30.48	—0.5	168,964	239,158	44.0	61.0	68.6	3,839	+ 661	3.908	660,339	Strong	15	
	25	29.65	—0.4	165,338	238,736	43.1	60.9	68.3	3,838	— 422	3.875	640,602	W.; strong	15	
	28	28.32	—0.3	156,473	234,978	40.9	60.0	65.6	3,827	—3,758	3.935	615,742		15	
	30	27.95	0.0	154,685	234,608	40.5	59.9	63.8	3,824	— 370	3.995	618,013		15	
Apr.	1	28.75	+0.5	159,122	235,989	41.5	60.2	65.5	3,835	+1,381				15	
	3	29.94	+0.5	163,354	235,640	42.5	60.1	67.0	3,842	— 349	4.178	682,416		15	
	5	30.48	+0.2	165,502	235,801	43.0	60.2	66.3	3,848	+ 161	4.117	681,778		15	
	6	30.55	0.0	166,124	236,064	43.2	60.3	67.3	3,849	+ 263	4.080	677,715		15	
	8	30.45	0.0	165,250	235,586	42.9	60.1	67.3	3,849	— 478	4.084	674,838		15	
	10	29.92	—0.3	164,571	236,944	42.8	60.5	67.7	3,847	+1,358	4.024	662,252		15	
	11	29.60	—0.3	162,618	236,222	42.3	60.3	67.7	3,846	— 722	4.097	666,291	Very strong	15	25
	15	28.78	—0.1	159,319	236,078	41.5	60.3	67.5	3,838	— 144	4.004	637,982		15	
	17	28.35	—0.2	157,777	236,172	41.2	60.3	65.9	3,829	+ 94	3.960	624,740		15	
	18	28.05	—0.3	156,194	235,737	40.8	60.2	65.7	3,826	— 435	3.903	609,600		15	
	20	27.20	—0.5	154,229	237,030	40.4	60.5	65.6	3,820	+1,293	3.869	596,692		15	
	22	26.30	—0.4	150,203	236,465	39.3	60.4	63.7	3,818	— 565	3.865	580,500		15	
	24	25.42	—0.4	147,717	237,331	38.8	60.6	63.9	3,809	+ 866	3.736	551,870		15	
	25	25.12	—0.3	146,517	237,281	38.5	60.6	61.5	3,808	— 50	3.776	553,230		15	
	27	24.75	—0.1	146,524	238,721	38.5	60.9	62.5	3,810	+1,440	3.812	558,479		15	
May	13 ::	19.20	—0.9	124,578	237,775	33.1	60.7	56.3	3,768	— 946	3.607	449,357		16	
	15 ::	17.65	—0.8	118,915	237,965	31.6	60.7	56.0	3,764	+ 190	3.637	432,438		15	
	16	17.00	—0.4	117,173	238,657	31.2	60.9	55.7	3,757	+ 692	3.913	458,494	Very strong	15	
	18	16.36	—0.2	113,504	237,484	30.3	60.6	54.0	3,754	—1,173	3.567	405,191		15	
	20	15.88	—0.3	110,938	236,621	29.6	60.4	53.3	3,749	— 863	3.588	398,086		15	
	22	15.24	—0.3	109,651	237,710	29.3	60.7	52.1	3,740	+1,089	3.538	387,984		15	
	23	14.75	—0.5	106,927	236,815	28.6	60.4	51.0	3,736	— 895	3.494	373,624		15	
	25	14.05	—0.3	103,390	235,886	27.7	60.2	49.9	3,730	— 929	3.512	363,109		15	
	27	13.68	—0.2	101,898	235,776	27.3	60.2	50.0	3,728	— 110	3.530	359,701		15	
	29	13.76	+0.2	100,767	234,344	27.0	59.8	51.0	3,728	—1,432	3.611	363,911	Up; strong	15	

* Conditions unfavorable.
† Small number of stations to-day owing to loss of time caused by failure of meter to work.
‡ The meter work was done in rain, which came down in torrents.
§ River full of surface drift.
‖ High waves.
¶ Some drift.
** Very foggy.
†† Drift.
:: Upstream eddy at first station from right bank.

NOTE.—The observations were taken with meter at six-tenths depth as the mean velocity at each velocity station.

Results of discharge observations, Old River, below Turnbull Island, 1889.

Date.	Red River Landing gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.			
Jan. 22*	27.50	+1.2	13,576	18,208	20.1	23.3	28.0	676	....	2.554	34,672	W.; light	8	8
28*	32.30	+0.4	17,266	18,466	22.6	23.6	34.1	765	+ 258	3.096	53,449	Very strong	8	8
Feb. 1*	33.20	+0.2	17,949	18,458	22.9	23.6	34.8	783	− 8	2.414	43,324		8	8
18	31.63	−0.7	16,206	17,871	22.6	22.8	33.0	717	− 587	2.437	39,487	N.; very strong	8	8
21	28.96	−0.9	15,317	18,911	22.3	24.2	33.3	687	+1,040	3.968	60,774		8	8
28	26.62	+0.9	14,142	19,413	21.0	24.8	29.5	675	+ 502	3.081	43,565		8	8
Mar. 11*	33.85	+0.1	18,329	18,329	23.5	23.5	33.9	780	−1,084	1.746	32,005		7	8
28	28.33	−0.3	14,717	18,755	21.5	24.0	29.8	683	+ 426	1.754	25,820		8	8
Apr. 23	25.84	−0.5	12,338	18,109	18.7	23.2	26.4	661	− 646	2.186	26,977		7	8
25	25.09	−0.3	11,992	18,264	18.4	23.4	26.0	652	+ 155	2.350	28,176		7	8
27	24.75	−0.1	11,705	18,234	17.9	23.4	25.3	655	− 30	2.234	26,147		7	8
May 13	19.29	−0.9	8,538	18,698	14.1	24.0	20.0	607	+ 464	3.180	27,146		6	8
18	16.42	−0.2	6,800	18,801	11.4	24.1	16.8	597	+ 103	3.054	20,764		5	8
23	14.75	−0.5	5,907	18,666	10.6	23.9	15.5	556	− 135	2.314	13,669	Up; strong	5	6
27	13.68	−0.1	4,923	18,154	9.3	23.3	12.3	532	− 512	1.032	5,079		4	7

*Flowing from the Mississippi.

NOTES.—The observations were taken with meter at six-tenths depth as mean velocity at each velocity station.

The river was flowing into the Mississippi also on the following days: February 16, 23, March 25, April 15, 17; and in the same direction, but with a velocity of less than .31 feet per second, March 4, 22, April 3, 20, May 29. The river had no perceptible currrent on the following days: January 16: February 11, 13, 14, March 5, 20, 21, April 4, 13, May 30. The river was flowing from the Mississippi on the following days: January 10, 12, 14, 23, 25, 29, February 6, March 8, 17, April 6, 8, 10, 11. Also in the same direction, but with a velocity of less than .31 feet per second, January 18, 19, March 6, 19.

Datum was taken at 36.85 on the Red River Landing gauge.

Results of discharge observations, Atchafalaya River, Simmsport, La., 1889.

Date.	Simmsport gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.	*Feet.*	*Feet.*	*Sq. Ft.*	*Sq. Ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*			
Jan. 17	20.40	+1.1	32,625	42,520	41.9	48.0	67.2	778		2.091	68,226		7	8
*21	25.00	+1.2	37,413	43,567	46.7	49.2	77.0	801	+1,047	2.833	105,981		7	7
24	27.35	+0.3	39,367	43,584	48.1	49.3	74.3	819	+ 17	2.733	107,587		8	8
31	31.10	+0.3	43,191	44,248	49.8	50.0	79.0	876	+ 664					7
Feb. 2	31.55	+0.1	43,301	43,963	49.2	49.7	81.5	880	— 285	3.275	141,810		7	7
5	31.58	0.0	41,746	42,381	47.4	47.9	75.9	880	—1,582					8
8	31.78	+0.1	40,364	40,824	45.7	46.1	77.5	883	—1,557	3.251	131,239		8	8
12	32.20	+0.1	42,119	42,208	47.5	47.7	78.1	886	+1,384	3.186	134,198		7	7
15	31.94	—0.2	42,690	43,008	48.3	48.6	77.6	884	+ 800					8
22	28.55	—0.7	40,695	43,941	48.1	49.7	77.1	846	+ 933	2.635	107,247		7	9
Mar. 2	28.12	+1.1	40,195	43,813	47.5	49.5	75.8	846	— 128	2.760	110,955		7	9
7	31.30	+0.4	42,998	43,880	48.9	49.6	79.1	880	+ 67	3.083	132,561	Across; strong	7	9
12	32.30	+0.2	43,818	43,818	49.5	49.5	80.2	885	— 62	3.080	134,973		7	9
20	30.80	—0.6	42,867	44,163	50.9	49.9	79.8	843	+ 345	2.916	124,983		8	9
22	30.00	—0.3	42,306	44,289	50.4	50.0	79.3	839	+ 126	2.784	117,793		7	7
26	28.32	—0.4	39,776	43,157	48.9	48.8	77.3	814	—1,132	2.735	108,776		7	7
Apr. 4	28.95	+0.3	40,821	43,689	49.4	49.4	79.0	827	+ 532	2.810	114,709		7	9
9	28.90	—0.3	40,155	43,062	48.7	48.7	77.5	825	— 627	2.735	109,832		7	9
13	27.80	—0.2	39,401	43,221	48.5	48.8	74.7	813	+ 159	2.636	103,845		7	9
16	27.40	—0.1	38,739	42,867	48.4	48.4	74.1	800	— 354	2.645	102,475		7	7
19	26.60	—0.3	37,587	42,353	47.3	47.9	73.1	795	— 514	2.421	90,903	Up; strong	6	7
23	25.20	—0.4	36,342	42,219	46.0	47.7	70.3	790	— 134	2.250	81,773		6	7
26	24.40	—0.2	36,135	42,645	45.9	48.2	70.0	788	+ 426	2.265	81,843		6	7
May 14	19.20	—0.6	32,380	42,941	42.1	48.5	65.3	769	+ 296	1.788	57,892		5	7
21	16.20	—0.4	29,847	42,649	39.8	48.2	61.7	749	— 293	1.448	43,220	Very strong	5	7
28	13.00	—0.3	27,226	42,161	38.8	47.6	58.0	701	— 488	1.325	36,066		4	7

* Observations not very accurate.

NOTE.—The observations were taken with meter at six-tenths depth as the mean velocity at each velocity station.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION IN SECRETARY'S OFFICE, MISSISSIPPI RIVER COMMISSION, OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT CARROLLTON, LOUISIANA, 1889.

The observations comprise a high-water set and a low-water set at the same section, and were made under direction of the fourth district engineer by Mr. L. Le Sassier and Mr. B. J. Oliveira.

The discharge section is shown to be at the same place as the discharge section of 1883, but slightly oblique to it. The discharge section of 1884 and 1885 is about 1,500 feet below that place.

The sounding and velocity stations were coincident and were located by means of fixed signals on shore; there were 17 stations in the high-water set; in the low-water set the number were reduced to 13 by omitting stations 2, 4, 5, and 8.

The intervals between stations ranged from 30 to 280 feet and 30 to 285 feet, respectively, in the two sets.

On 27 days velocities were observed but no soundings taken, and for these days soundings were interpolated from the two nearest days on which soundings were observed, proportional to time and with proper correction for change of stage.

The length of time velocity was observed at each station was generally 2 minutes, but varied from 1 to 6 minutes.

The Price current meter No. 25 was used for measuring all the velocities; it is reported that the meter was rated during the high-water series and again at the close of the low water series; the computed values of *x and †y from the latter set of rating observations have been received and are reduced by the usual method; the resulting values of the constants, as given in the following table, have been used in reducing all the discharges.

Designation of meter.	Date and locality of rating observations.	No. of observations.	a	b	Mean error of observation.	Mean error of a	Mean error of b
Price meter No. 25.	December 13, 1889, near Carrollton, La.	5	3.99	+0.395	±0.113	±0.081	±0.103

The regular Carrollton gauge was read at about 10 a. m. and these readings are given in the tabulation and used in computing datum areas. The zero of the gauge is 20.91 feet above the Cairo datum plane, survey Mississippi River.

The datum line is taken at 13.54 feet on the gauge, that being the assumed datum for the 1883 series; this was also datum line of 1884–'85 series.

Datum width for the high-water period is taken at 2,400 feet and for the low-water period at 2,450 feet; for the latter period the widths corresponding to 7.60 and 5.30 feet on the gauge are taken at 2,399 and 2,347 feet, respectively.

The discharges were computed in the same manner as for Warrenton, described on page 3512; the corrections applied to the computed results vary from 0 to + 785 cubic feet.

A plate has been prepared showing mean velocities, areas and discharges plotted to gauge heights, and the datum areas and gauge readings to time abscissas; no areas derived from interpolated soundings are plotted. Two cross-section profiles are also shown on the plate.

OFFICE SECRETARY MISSISSIPPI RIVER COMMISSION,
September, 1890.

* Registrations per second. † Velocity in feet per second.

Results of discharge observations, Mississippi River, Carrollton, La., 1889.

Date.	Carrollton gauge. Reading.	Carrollton gauge. Rise or fall in the preceding 24 hours.	Cross section of discharge. Area. Water.	Area. Below datum.	Depth. Mean.	Depth. Mean datum.	Depth. Maximum.	Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
1889.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*			
Feb. 22	8.82	− 0.3	176,344	187,561	74.9	78.2	107.6	2,353	....	3.836	676,384	Upstream; strong		
23	8.56	− 0.2	173,985	185,829	74.1	77.4	107.0	2,347	− 1,737	3.735	649,816	Calm		
25	7.80	− 0.4	170,538	184,145	72.8	76.7	106.1	2,341	− 1,679	3.669	625,752	Fresh		
26	7.50	− 0.3	172,485	186,812	73.6	77.8	109.1	2,344	+ 2,667	3.760	648,537	Upstream; strong		
27	7.50	0.0	172,438	186,765	73.6	77.8	106.0	2,344	− 47	3.854	664,555	Downstream; strong		
28	7.75	+ 0.3	173,668	187,405	74.1	78.1	107.0	2,345	+ 640	3.639	632,041	Calm		17
Mar. 2	9.00	+ 0.7	178,370	189,162	75.8	78.8	109.0	2,354	+ 1,757	3.920	699,132	....do		
4	10.10	+ 0.4	180,601	188,797	76.4	78.7	110.4	2,365	− 365	4.156	750,603	Across stream; strong		
6	10.70	+ 0.4	182,090	188,853	77.1	78.7	112.4	2,363	+ 56	4.228	769,863	Downstream; fresh		
7	10.70	+ 0.1	181,818	188,581	76.9	78.6	115.0	2,363	− 272	4.217	766,739	Calm		
8	11.00	+ 0.2	181,273	187,328	76.6	78.1	114.7	2,368	− 1,253	4.395	796,635	Downstream; strong		
9	11.00	+ 0.1	* 180,141	186,196	76.1	77.6	113.4	2,368	− 1,132	4.528	815,738	Calm	17	
11	11.25	+ 0.1	178,379	183,843	75.2	76.6	111.0	2,372	− 2,353	4.556	812,631	Downstream; strong		....
12†	11.25	+ 0.1	* 178,567	184,031	75.3	76.7	111.4	2,372	+ 188	4.422	789,641	Across stream		17
13	11.50	+ 0.2	179,352	184,224	75.5	76.8	112.1	2,376	+ 193	4.457	799,422	Calm		....
14†	11.50	0.0	* 178,902	183,774	75.3	76.6	112.6	2,376	− 450	4.459	797,792	Upstream; strong		17
15	11.50	− 0.1	178,356	183,228	75.1	76.3	113.0	2,376	− 546	4.352	776,286	Downstream; light		....
16‡	11.50	− 0.1	179,498	184,370	75.5	76.8	115.0	2,376	+ 1,142	4.218	757,078	....		17
18	11.50	− 0.1	* 178,550	183,422	75.1	76.4	112.7	2,376	− 948	4.118	735,343	Downstream		17
19	11.00	0.0	176,867	182,922	74.7	76.2	111.0	2,368	− 500	4.049	716,079	Downstream; very strong		17
20	10.75	− 0.7	174,744	181,388	73.9	75.6	110.0	2,363	− 1,534	4.246	741,946	Calm		17
21	10.50	− 0.3	173,658	180,898	73.5	75.4	113.0	2,363	− 490	4.060	704,998	....do		17
22§	10.25	0.0	173,206	181,038	73.4	75.4	111.5	2,361	+ 140	4.105	710,942	....		17
23§	9.90	− 0.4	172,208	180,871	73.0	75.4	111.7	2,360	− 167	....	....	Upstream	....	17
25†	9.70	− 0.3	176,694	185,833	74.9	77.4	107.7	2,360	+ 4,962	3.917	692,192	Across stream; strong		17
26§†	9.40	− 0.3	* 173,205	183,046	73.6	76.3	108.8	2,354	− 2,787	3.847	666,235	Downstream		....
27	9.25	− 0.1	170,144	180,337	72.3	75.1	110.0	2,352	− 2,709	3.619	615,767	Calm		17
28	9.00	− 0.1	173,099	183,886	73.6	76.6	108.0	2,352	+ 3,549	3.563	616,690	Across stream		17
29	9.00	− 0.1	* 171,118	181,905	72.8	75.8	108.8	2,352	− 1,981	3.510	600,630	Calm	17	....
30	8.90	− 0.3	168,912	179,964	71.9	75.0	109.5	2,351	− 1,941	3.475	587,077	....do		17
Apr. 1‡	8.90	+ 0.1	* 171,351	182,373	72.9	76.0	106.2	2,351	+ 2,409	3.416	585,322	Upstream		....
2	9.25	+ 0.2	173,337	183,530	73.7	76.5	106.0	2,352	+ 1,157	3.730	646,619	Calm		17
3	9.40	+ 0.3	* 174,732	184,573	74.2	76.9	106.3	2,354	+ 1,043	3.810	665,815	....do		....
4	9.90	+ 0.2	176,967	185,630	75.0	77.3	108.0	2,360	+ 1,057	3.976	703,649	Downstream; strong		17

* Soundings interpolated. † Rough water. ‡ Very rough water. § Misty or foggy.

NOTE.—The observations were taken with meter at six-tenths depth as the mean velocity at each velocity station.

Results of discharge observations, Mississippi River, Carrollton, La., 1889.—Continued.

Date.		Carrollton gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
		Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
				Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1889.		Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.			
Apr.	5	9.80	+ 0.1	* 177, 144	186, 045	75.1	77.5	108.9	2, 360	+ 415	3.965	702, 418	Calm		....
	6	9.90	+ 0.1	* 177, 733	186, 396	75.3	77.7	110.1	2, 360	+ 351	4.122	732, 608	Downstream; strong		....
	8	8.90	0.0	178, 479	187, 142	75.6	78.0	112.2	2, 360	+ 746	4.106	732, 840	Across stream; light		17
	9	9.80	— 0.1	175, 048	183, 949	74.2	76.6	113.0	2, 360	— 3, 193	4.036	706, 431	Calm		17
	10	9.80	— 0.1	* 175, 305	184, 206	74.3	76.8	112.9	2, 360	+ 257	3.770	660, 964	...do		....
	13†	9.60	— 0.2	* 175, 710	185, 087	74.5	77.1	112.8	2, 360	+ 881	3.697	649, 579	Upstream; strong		....
	15†	9.50	— 0.4	176, 006	185, 613	74.7	77.3	112.0	2, 356	+ 526	3.629	638, 711	Downstream; strong		17
	16	9.40	0.0	* 173, 697	183, 538	73.8	76.5	111.5	2, 354	— 2, 075	3.598	624, 991	Calm		....
	17	9.30	— 0.1	171, 337	181, 411	72.8	75.6	111.0	2, 352	— 2, 127	3.453	591, 626	...do		17
	22†	8.30	— 0.2	* 170, 162	182, 599	72.5	76.1	109.5	2, 347	+ 1, 188	3.508	596, 955	Upstream; strong		....
	23	7.90	— 0.2	169, 491	182, 872	72.3	76.2	109.0	2, 345	+ 273	3.667	621, 544	Calm	17	17
	24†	7.70	— 0.2	* 169, 578	183, 430	72.3	76.4	108.3	2, 344	+ 558	3.606	611, 581	Strong		....
	25 ¶	7.50	0.0	* 169, 692	184, 019	72.4	76.7	107.6	2, 344	+ 589	3.619	614, 119	Downstream; strong		....
	26	7.40	— 0.2	169, 996	184, 560	72.5	76.9	107.0	2, 344	+ 541	3.560	605, 224	Calm		17
	27†	7.40	— 0.2	* 169, 654	184, 218	72.4	76.8	107.0	2, 344	— 342	3.562	604, 334	....		....
	29 ¶	7.25	— 0.1	* 168, 712	183, 632	72.0	76.5	106.8	2, 344	— 586	3.561	600, 783	Across stream; strong		....
May	1	7.50	+ 0.3	168, 546	182, 878	71.9	76.2	107.0	2, 344	— 759	3.592	605, 455	Downstream; light		17
	2	7.60	+ 0.2	168, 439	182, 529	71.9	76.1	105.0	2, 344	— 344	3.628	611, 036	...do		17
	3 §	7.75	0.0	* 169, 142	182, 879	72.1	76.2	105.3	2, 345	+ 350	3.829	647, 580	....		....
	4	7.75	0.0	169, 508	183, 245	72.3	76.4	105.4	2, 345	+ 366	3.584	607, 442	Down stream		17
	6‡	7.70	— 0.2	170, 056	183, 911	72.5	76.6	107.0	2, 345	+ 666	3.445	585, 780	Up; strong	14	17
	7	7.50	— 0.3	168, 812	183, 139	72.0	76.3	106.5	2, 344	— 772	3.438	580, 376	Up; very strong	17	17
	8	7.25	— 0.2	169, 265	184, 185	72.2	76.7	109.0	2, 344	+ 1, 046	3.392	574, 192	Upstream; light	17	17
	9	6.90	— 0.4	* 168, 063	183, 806	71.8	76.6	109.5	2, 342	— 379	3.349	562, 907	Across stream	17	....
	10	6.50	— 0.5	166, 736	183, 410	71.3	76.4	110.0	2, 337	— 396	3.258	543, 266	Calm	16	17
	11	6.15	— 0.4	166, 440	183, 880	71.7	76.6	106.0	2, 320	+ 470	3.266	543, 633	...do	16	16
	13†	5.20	— 0.3	* 164, 634	184, 275	71.3	76.8	105.1	2, 310	+ 395	3.206	527, 885	....	16	....
	14	4.80	— 0.5	163, 858	184, 388	71.3	76.8	104.7	2, 298	+ 113	2.896	474, 493	Calm	16	16
	15	4.30	— 0.4	162, 846	184, 500	71.2	76.9	105.0	2, 287	+ 112	2.773	451, 540	...do	16	16
	16	3.85	— 0.4	162, 006	184, 690	71.0	77.0	104.3	2, 282	+ 190	2.725	441, 398	Upstream; light	16	16
	17†	3.60	— 0.3	* 161, 452	184, 692	70.9	77.0	104.0	2, 276	+ 2	2.635	425, 489	Upstream; strong	15	....
	18	3.40	0.0	161, 010	184, 687	70.9	77.0	103.7	2, 270	— 5	2.626	422, 735	Calm	15	15
	20	3.15	— 0.2	160, 041	184, 270	70.7	76.8	102.4	2, 264	— 417	2.678	428, 580	Downstream; light	15	15
	21	3.15	0.0	* 159, 934	184, 163	70.6	76.7	102.3	2, 264	— 107	2.596	415, 251	....	15	....
	22	2.90	— 0.1	159, 270	184, 045	70.6	76.7	102.0	2, 257	— 118	2.619	417, 186	Calm	15	15
	23	2.70	— 0.2	* 158, 893	184, 123	70.5	76.7	101.8	2, 255	+ 78	2.635	418, 775	Calm	15	....
	25	2.50	— 0.1	158, 552	184, 248	70.3	76.8	101.7	2, 255	+ 125	....	....	Upstream; very strong	....	15
	27	2.50	+ 0.1	* 158, 340	184, 036	70.2	76.7	101.6	2, 255	— 212	2.429	384, 621	Across stream	15	....
	28	2.50	— 0.2	158, 246	183, 942	70.2	76.6	101.6	2, 255	— 94	2.392	378, 484	Calm	15	15

Nov. 14	0.90	+ 0.1	143,767	173,877	62.2	71.0	100.4	2,312	−10,065	2.984	429,070	....do	18	13
15	1.10	+ 0.2	142,836	172,486	61.7	70.4	100.5	2,315	− 1,391	2.978	425,417	....do	13	13
18†	1.50	0.0	148,169	176,893	63.9	72.2	100.5	2,318	+ 4,407	3.016	446,830	East	13	13
19	1.50	+ 0.1	147,642	176,366	63.7	72.0	99.6	2,318	− 527	3.122	460,894	Calm	13	13
20	2.00	+ 0.5	148,058	175,619	63.8	71.7	102.6	2,320	− 747	3.156	467,236	Southeast; very strong	13	13
21	2.50	+ 0.4	*149,060	175,468	64.0	71.6	104.2	2,330	− 151	3.163	471,403	West; very strong	13	13
22	2.50	+ 0.1	149,002	175,410	63.9	71.6	105.4	2,330	− 58	3.142	468,115	Downstream	13	13
23	2.90	+ 0.3	149,792	175,270	64.2	71.5	106.3	2,335	− 140	3.154	472,494	Calm	18	18
25	3.90	+ 0.7	151,254	174,392	64.7	71.2	107.0	2,336	− 878	3.240	490,000	....do	18	13
26‖	4.45	+ 0.7	151,803	173,656	64.8	70.9	106.0	2,342	− 736	3.375	512,347	....do	18	13
27	5.00	+ 0.4	153,200	173,764	65.3	70.9	107.0	2,345	+ 108	3.573	547,369	Northwest; strong	12	13
28†	5.30	+ 0.4	153,289	173,149	65.3	70.7	107.0	2,347	− 615	3.579	548,595	Strong	12	13
29	5.60	+ 0.2	155,794	174,951	66.1	71.4	108.0	2,356	+ 1,802	3.575	556,992	Calm	18	13
30	5.80	+ 0.2	156,208	174,898	66.0	71.4	108.0	2,365	− 53	3.547	554,069	....do	13	13
Dec. 2	6.00	+ 0.1	159,175	177,393	67.1	72.4	109.4	2,371	+ 2,495	3.562	567,017	....do	13	13
3	6.20	+ 0.1	159,867	177,609	67.4	72.5	110.0	2,372	+ 216	3.604	590,478	....do	13	13
4	6.30	+ 0.1	161,472	178,976	68.0	73.1	109.6	2,373	+ 1,367	....	....	....do	....	13
5	6.50	+ 0.2	163,167	180,195	68.7	73.5	110.2	2,375	+ 1,219	3.765	614,402	....do	13	13
6	6.50	+ 0.1	*163,175	180,203	68.7	73.6	110.0	2,375	+ 8	3.790	618,491	....do	13	13
7‖	6.90	+ 0.2	164,243	180,319	68.9	73.6	110.2	2,383	+ 116	3.736	613,649	....do	13	13
9**‖	7.40	+ 0.5	164,836	179,717	68.9	73.4	110.5	2,394	− 602	3.835	632,115	....	13	13
10††	7.60	+ 0.1	164,855	179,257	68.7	73.2	110.2	2,399	− 460	3.901	643,153	Calm	13	13
11‖	7.60	0.0	164,654	179,056	68.6	73.1	111.0	2,399	− 201	3.912	644,119	....do	13	....
12‖	7.60	0.0	164,553	178,955	68.6	73.0	109.8	2,399	− 101	3.931	646,839	....	18	....

* Soundings interpolated.
† Rough water.
‡ Conditions unfavorable.
‖ Foggy or misty.
¶ Very rough water.
§ Conditions excellent.
** Drift very thick.
†† Very foggy.

APPENDIX C 6.

TABULATED RESULTS, WITH FIELD AND OFFICE REPORTS, OF DISCHARGE MEASUREMENTS ON THE MISSISSIPPI AND ATCHAFALAYA RIVERS AND BAYOU LA FOURCHE, 1890.

[When not otherwise stated, results are derived from final reduction at the office of the Secretary Mississippi River Commission, 1890-'91.]

CONTENTS.

MEMORANDA TO ACCOMPANY TABULATED RESULTS OF FINAL REDUCTION OF DISCHARGE OBSERVATIONS MADE AT WILSON POINT, LOUISIANA, AND AT BREAK IN SKIPWITH LEVEE, MISSISSIPPI, 1890. MR. F. P. SPALDING, CHIEF OF PARTY.

The results were obtained in the usual manner, except the discharge over bank east of section which the observer states "was obtained by taking meter observations and soundings at approximately equal distances and averaging them to give a mean velocity and depth. The measurement of this discharge was not made on line of the section but in three separate parts." The results of the overflow discharge are from the field computation, the observation notes not having been received.

For velocity observations of January 28 and 31 and February 11 and 12 (except at one station on February 11) Price current meter No. 4 was used; the field notes state that results of a rating previously made at Ashton are, $y = 1.921\,x + 0.321$, in which y = velocity in feet per second and x = registrations of meter per second. These values for this meter have been adopted in the final reduction.

For all other velocity observations Price meter No. 5 was used; three sets of rating observations were made with this meter during the season, the results of which, derived from final reduction in this office, are given in the following table:

Designation of meter.	Date and locality of rating observations.	No. of observations.	a	b	Mean error of observations.	Mean error of a	Mean error of b
Price meter No. 5.	February 5, 1890, Duncansby, Miss.	*21	3.7581	+0.271	±0.124	±0.087	±0.151
Do	February 26, 1890, Wilson Point, La.	†24	3.7650	+0.2529	±0.048	±0.027	±0.045
Do	April 11, 1890, Wilson Point, La.	*29	3.791	+0.2042	±0.145	±0.084	±0.132

* In still water. † In running water.

It is reported that this meter was taken apart and cleaned on February 11; therefore the results of the first rating were used in computing discharges to February 11. For river discharges after that date the equation $y = 3.7675\,x + 0.2479$ was used; this was obtained by combining the results of ratings made February 26 and April 11, giving weight to the values of a and b inversely as the squares of their mean errors in the two series.

For computing discharges through the break in Skipwith levee, since the velocities were low, the results of April 11 rating were used, as they agree more closely with former ratings of this meter where low velocities were observed.

Datum was assumed at 41.83 feet on the local gauge as in computation of previous Wilson Point discharge measurements.

OFFICE SECRETARY MISSISSIPPI RIVER COMMISSION,
May 30, 1890.

Results of discharge observations, Mississippi River, Wilson Point, La.

Date.	Gauges.			Cross-section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Discharge over bank, east of section, per second.‡	Total discharge of river per second.	No. of velocity stations.	No. of soundings.
	Lake Providence.	Local.*	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.							
				Water.	Below datum.†	Mean.	Mean datum.	Maximum.								
1890.	Feet.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.	Cubic feet.	Cubic feet.		
Jan. 28	34.9	38.73	+0.3	147,690	159,296	39.4	42.5	78	3,744		7.386	1,090,788	0	1,090,788		48
29	35.2		+0.3													
30	35.6		+0.4													
31	36.1	39.83	+0.5	153,046	160,534	40.9	42.9	79	3,744	+ 1,238	6.971	1,066,966	0	1,066,966		41
Feb. 1	36.4		+0.3													
2	36.8		+0.4													
3	37.1	40.79	+0.3	153,814	157,707	41.1	42.1	80	3,744	— 2,827	7.499	1,153,454	0	1,153,454		46
4	37.4	41.03	+0.3	165,766	168,761	44.3	45.1	82	3,744	+11,054	7.029	1,165,164	0	1,165,164		49
5	37.5	41.25	+0.1	159,219	161,391	42.5	43.1	81	3,744	— 7,370	6.870	1,093,796	5,000	1,098,796		52
6	37.8	41.42	+0.3	163,783	165,318	43.7	44.2	82	3,744	+ 3,927	6.847	1,121,471	8,000	1,129,471		43
7	38.2		+0.4													
8	38.3	41.98	+0.1	171,563		45.8			3,744		6.874	1,179,385	16,000	1,195,385		§42
9	38.4		+0.1													
10	38.5	42.23	+0.1	178,861	177,363	47.8	47.4	81	3,744	+12,045	6.834	1,222,351	20,000	1,242,351		40
11	38.6	42.28	+0.1	175,172	173,487	46.8	46.3	81	3,744	— 3,876	6.696	1,172,882	23,000	1,195,882		42
12	38.6	42.27	0.0	173,290	171,643	46.3	45.8	80	3,744	— 1,844	6.403	1,109,604	23,000	1,132,604		38
13	38.6	42.28	0.0	174,141	172,456	46.5	46.1	80	3,744	+ 813	6.317	1,100,104	23,000	1,123,104	10	40
14	38.7	42.39	+0.1	177,392	175,295	47.4	46.8	80	3,744	+ 2,8[illegible]9	6.330	1,122,924	25,000	1,147,924		41
15	38.7	42.39	0.0	171,602	169,505	45.8	45.3	80	3,744	— 5,790	6.190	1,062,233	25,000	1,087,233		41
16	38.7		0.0													
17	38.8	42.45	+0.1	175,514	173,193	46.9	46.3	80	3,744	+ 8,688	6.187	1,077,060	26,000	1,103,060		42
18	38.8		0.0													
19	38.9		+0.1													
20	39.0	42.78	+0.1	177,728	174,171	47.5	46.5	80	3,744	+ 978	5.982	1,063,254	28,000	1,091,251		38
21	39.1	42.83	+0.1	179,984	176,240	48.1	47.1	80	3,744	+ 2,069	6.327	1,138,692	28,000	1,166,692		41
22	39.2	42.98	+0.1	182,286	177,980	48.7	47.5	80	3,744	+ 1,740	6.012	1,095,979	29,000	1,124,979		42
23	39.3		+0.1													
24	39.4	43.21	+0.1	178,931	173,764	47.8	46.4	81	3,744	— 4,216	6.221	1,113,174	3,0000	1,143,174		41
25	39.5	43.27	+0.1	181,393	176,002	48.4	47.0	80	3,744	+ 2,238	6.106	1,107,519	30,000	1,137,519		44
26	39.5	43.27	0.0	180,075	174,684	48.1	46.7	80	3,744	— 1,318	5.970	1,075,131	30,000	1,105,131		40
27	39.5	43.38	0.0	183,736	177,933	49.1	47.5	80	3,744	+ 3,249	5.786	1,063,172	31,000	1,094,172		42
28	39.5		0.0													

* Zero at same elevation as zero of Lake Providence gauge = 89.62 feet above the Cairo datum plane, Survey Mississippi River.
† Datum was assumed at 41.83 feet on the local gauge.
‡ From field computation, by chief of party.
§ Interpolated.

NOTE.—Velocities were observed with Price current meters, Nos. 4 and 5, at six-tenths depth from the surface as mean velocity at each velocity station.

Result of discharge observations, Mississippi River, Wilson Point, La.—Continued.

Date.	Gauges. Lake Providence.	Gauges. Local.*	Gauges. Rise or fall in the preceding 24 hours.	Cross section of discharge. Area. Water.	Cross section of discharge. Area. Below datum.†	Cross section of discharge. Depth. Mean.	Cross section of discharge. Depth. Mean datum.	Cross section of discharge. Depth. Maximum.	Cross section of discharge. Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Discharge over bank, east of section, per second.‡	Total discharge of river per second.	No. of velocity stations.	No. of soundings.
1890.	Feet.	Feet.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.	Feet.	Feet.	Sq. feet.	Feet.	Cubic feet.	Cubic feet.	Cubic feet.		
Mar. 1	39.4	43.18	—0.1	179,789	174,735	48.0	46.7	80	3,744	—3,198	5.801	1,043,044	30,000	1,073,044		42
2	39.4		0.0													
3	39.4	43.23	0.0	183,555	178,313	49.0	47.6	80	3,744	+3,578	5.911	1,084,915	30,000	1,114,915		41
4	39.5	43.31	+0.1	184,903	179,362	49.4	47.9	81	3,744	+1,049	5.778	1,067,372	31,000	1,098,372		44
5	39.6	43.45	+0.1	185,679	179,614	49.6	48.0	80	3,744	+ 252	5.942	1,103,277	33,000	1,136,277		35
6	39.8	43.53	+0.2	190,692	184,327	50.9	49.2	80	3,744	+4,713	6.006	1,145,360	34,000	1,179,360		42
7	40.0	43.81	+0.2	193,048	185,635	51.6	49.6	81	3,744	+1,308	5.814	1,122,367	40,000	1,162,367		43
8	40.2	43.93	+0.2	195,692	187,830	52.3	50.2	81	3,744	+2,195	5.840	1,142,839	43,000	1,185,839		43
9	40.3		+0.1													
10	40.4	44.26	+0.1	197,730	188,632	52.8	50.4	81	3,744	+ 802	5.973	1,180,951	47,000	1,227,951		42
11	40.5	44.30	+0.1	199,068	189,820	53.2	50.7	82	3,744	+1,188	6.238	1,241,797	47,000	1,288,797		37
12	40.7	44.56	+0.2	202,916	192,695	54.2	51.5	81	3,744	+2,875	5.621	1,140,538	50,000	1,190,538		43
13	40.9	44.68	+0.2	203,930	193,260	54.5	51.6	81	3,744	+ 565	5.533	1,128,406	50,000	1,178,406		42
14	40.9	44.71	0.0	205,205	194,422	54.8	51.9	81	3,744	+1,162	5.675	1,164,569	50,000	1,214,569		42
15	41.0	44.81	+0.1	199,593	188,436	53.3	50.3	82	3,744	—5,986	5.865	1,170,525	50,000	1,220,525		43
16	40.9		—0.1													
17	40.7	44.73	—0.2	200,443	189,585	53.5	50.6	81	3,744	+1,149	5.914	1,185,377	47,000	1,232,377		42
18	40.6	44.69	—0.1	199,451	188,743	53.3	50.4	82	3,744	— 842	6.109	1,218,413	45,000	1,263,413		43
19	40.4	44.43	—0.2	197,027	187,293	52.6	50.0	81	3,744	—1,450	6.056	1,193,168	38,000	1,231,168	10	43
20	40.3	44.30	—0.1	199,990	190,742	53.4	50.9	81	3,744	+3,449	5.654	1,130,711	35,000	1,165,711		43
21	40.2	44.29	—0.1	200,678	191,468	53.6	51.1	80	3,744	— 726	5.433	1,090,294	35,000	1,125,294		43
22	40.3		+0.1													
23	40.2		—0.1													
24	40.2	44.31	0.0	201,354	192,069	53.8	51.3	80	3,744	+ 601	5.824	1,172,684	35,000	1,207,684		43
25	40.2	44.33	0.0	200,431	191,071	53.5	51.0	80	3,744	— 998	6.082	1,218,946	35,000	1,253,946		43
26	40.2		0.0													
27	40.0		—0.2													
28	39.9	44.05	—0.1	199,361	191,049	53.2	51.0	79	3,744	— 22	5.947	1,185,677	30,000	1,215,677		
29	39.8		—0.1													
30	39.6		—0.2													
31	39.6	43.58	0.0	196,146	189,504	52.4	50.6	78	3,744	—1,455	5.982	1,173,386	25,000	1,198,386		
Apr. 1	39.6															42
2	39.5	43.55	—0.1	195,601	189,161	52.2	50.5	78	3,744	— 438	5.849	1,144,165	23,000	1,167,165		
3	39.6	43.68	+0.1	195,887	188,961	52.3	50.5	79	3,744	— 200	6.034	1,182,027	23,000	1,205,027		
4	39.4	43.43	—0.2	196,501	190,511	52.5	50.9	78	3,744	+1,550	5.979	1,174,924	21,500	1,196,424		
5	39.3	43.28	—0.1	195,828	190,399	52.3	50.9	79	3,744	— 112	5.732	1,122,393	20,000	1,142,393		
6	39.3		0.0													

7	39.3	43.28	0.0	195,314	189,885	52.2	50.7	78	3,744	− 514	5.776	1,128,112	19,000	1,147,112		
8	39.3	43.28	0.0	195,719	190,290	52.3	50.8	78	3,744	+ 405	5.701	1,115,742	18,000	1,133,742		
9	39.3	43.28	0.0	196,042	190,613	52.4	50.9	78	3,744	+ 323	5.622	1,102,056	17,000	1,119,056	10	42
10	39.3	43.23	0.0	192,041	186,790	51.8	49.9	78	3,744	− 3,814	5.728	1,099,945	16,000	1,115,945		
11	39.3	43.23	0.0	191,808	186,566	51.2	49.8	77	3,744	− 233	5.712	1,095,566	15,000	1,110,566		
12	39.3	43.23	0.0	193,538	188,296	51.7	50.3	78	3,744	+ 1,730	5.909	1,143,563	15,000	1,158,563		41
13	39.3	......	0.0	......	......	......	......	......	......	......	......	......	......	......		
14	39.3	43.23	0.0	192,974	187,732	51.5	50.1	77	3,744	− 564	5.588	1,078,298	15,000	1,093,298		
15	39.2	43.13	− 0.1	194,324	189,457	51.9	50.6	77	3,744	+ 1,725	5.604	1,088,952	14,000	1,102,952		
16	39.3	......	+ 0.1	......	......	......	......	......	......	......	......	......	......	......		
17	39.3	43.13	0.0	194,305	189,438	51.9	50.6	78	3,744	− 19	5.513	1,071,221	14,000	1,085,221		
18	39.2	43.08	− 0.1	194,147	189,467	51.9	50.6	77	3,744	+ 29	5.566	1,080,699	13,000	1,093,699		
19	39.3	43.01	+ 0.1	195,489	191,071	52.2	51.0	77	3,744	+ 1,604	5.523	1,079,777	12,000	1,091,777		
20	39.3	......	0.0	......	......	......	......	......	......	......	......	......	......	......		
21	39.3	43.05	0.0	191,652	187,084	51.2	50.0	77	3,744	− 3,987	5.701	1,092,657	12,000	1,104,657	11	
22	39.3	43.04	0.0	192,149	187,619	51.3	50.1	77	3,744	+ 535	5.603	1,076,696	12,000	1,088,696		
23	39.3	......	0.0	......	......	......	......	......	......	......	......	......	......	......		42
24	39.4	43.08	+ 0.1	194,273	189,593	51.9	50.6	77	3,744	+ 1,974	5.736	1,114,351	12,000	1,126,351		
25	39.3	43.01	− 0.1	194,199	189,781	51.9	50.7	76	3,744	+ 188	5.628	1,092,930	11,000	1,103,930		
26	39.1	42.78	− 0.2	195,909	192,352	52.3	51.4	77	3,744	+ 2,571	5.563	1,089,843	9,000	1,098,843		
27	38.9	......	− 0.2	......	......	......	......	......	......	......	......	......	......	......		
28	38.7	42.33	− 0.2	189,429	187,557	50.6	50.1	75	3,744	− 4,795	5.479	1,037,800	5,000	1,042,800		
29	38.5	42.13	− 0.2	189,457	188,334	50.6	50.3	76	3,744	+ 777	5.431	1,028,916	0	1,028,916		
30	38.4	42.01	− 0.1	186,693	186,019	49.9	49.7	75	3,744	− 2,315	5.524	1,031,336	0	1,031,336		
May 1	38.3	......	− 0.1	......	......	......	......	......	......	......	......	......	......	......		
2	38.2	41.81	− 0.1	185,774	185,849	49.6	49.6	75	3,744	− 170	5.501	1,021,930	0	1,021,930		
3	38.1	......	− 0.1	......	......	......	......	......	......	......	......	......	......	......		......
4	38.1	......	0.0	......	......	......	......	......	......	......	......	......	......	......	10	......
5	38.0	41.73	− 0.1	189,393	189,767	50.6	50.7	75	3,744	+ 3,918	5.372	1,017,338	0	1,017,338		43
6	37.9	41.58	− 0.1	189,918	190,854	50.7	51.0	73	3,744	+ 1,087	5.344	1,014,895	0	1,014,895		42
7	37.9	41.48	0.0	§189,628	190,938	50.6	51.0	......	3,744	+ 84	5.172	980,701	0	980,701		23‡

* Zero at same elevation as zero of Lake Providence gauge=89.62 feet above the Cairo datum plane, Survey Mississippi River.
† Datum was assumed at 41.83 feet on the local gauge.
‡ From field computation, by chief of party.
§ Adopted from field computation, as sounding notes were incomplete.

NOTE.—Velocities were observed wiih Price current meters, Nos. 4 and 5, at six-tenths depth from the surface as mean velocity at each velocity station.

Results of discharge observations at break in Skipwith Levee, Mississippi.

Date.	Gauges.			Cross section of discharge.						Mean velocity per second.	Discharge per second.	Method.
	Lake Providence.	Wilson Point discharge section.	Rise or fall in the preceding 24 hours.	Area. Water.	Area. Below datum.	Depth. Mean.	Depth. Mean datum.	Depth. Maximum.	Width.			
1890.	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*	
Apr. 2	39.5	43.55	−0.1	34,118	....	33.4	....	52	1,020	1.867	63,704	Meter at surface.*
5	39.3	43.28	−0.1	39,525	....	35.9	....	50	1,100	2.097	82,870	Meter 0.6 of depth from surface.
9	39.3	43.28	0.0	39,684	....	32.8	....	51	1,210	1.877	74,480	
14	39.3	43.23	0.0	40,424	....	32.6	....	51	1,240	1.920	77,648	
16	39.3	43.13	+0.1	41,875	....	33.8	....	50	1,240	1.772	74,188	
19	39.3	43.01	+0.1	41,014	....	33.1	....	48	1,240	1.548	63,477	
24	39.4	43.08	+0.1	42,508	....	33.7	....	46	1,260	1.669	70,954	
28	38.7	42.33	−0.2	42,210	....	33.5	....	48	1,260	1.521	64,210	
May 1	38.3	41.91	−0.1	39,970	....	31.7	....	51	1,260	1.063	42,487	
6	37.9	41.58	−0.1	38,728	....	30.7	....	45	1,260	0.996	38,566	

* Four-fifths of surface velocity is taken as mean velocity at velocity stations.

NOTES.—The break is 529 miles below Cairo and near Skipwith, Miss. The measurements were taken on a section in line with the ends of the broken levee. There is a small excess of computed discharge since the direction of the flow was not perpendicular to the section.

Zeros of both gauges are 89.62 feet above Cairo datum plane, Survey Mississippi River.

Results of discharge observations, Mississippi River, below New Madrid, Mo.

Date.	New Madrid gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1890.	*Feet.*	*Feet.*	*Sq. feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*			
Mar. 25	36.6	0.0	239,698	173,472	39.5	28.8	51.8	6,066		5.546	1,329,387	XI—Slight	12	37
Apr. 3	37.7	−0.2	246,492	172,984	40.3	28.8	52.0	6,114	−488			VI—Brisk		48
9	37.3	−0.4												
10	36.9	−0.4	240,893	172,525	39.5	28.7	53.0	6,106	−459	5.290	1,274,819	X—Brisk	22	65
11	36.2	−0.7	236,028	171,558	38.7	28.5	52.5	6,091	−967	5.231	1,234,597	VI—Brisk	23	67
12	35.6	−0.6	233,081	172,879	38.3	28.7	53.0	6,085	+1,321	5.209	1,214,031	VII—Brisk	23	65
13	34.9	−0.7												
14	34.2	−0.7	226,213	174.597	37.3	29.0	52.0	6,058	+1,718	4.746	1,078,506	XII—Brisk	23	65

NOTES.—Discharge measurements were made at the high water section of 1888–'89, about 5 miles below New Madrid, Mo.; for description of location, etc., see page 3497.

Datum line is taken same as in 1888–'89 at 25.6 feet on the New Madrid gauge, whose zero is 275.80 feet above the Cairo datum plane, Survey Mississippi River. Velocities were measured with Price meter No. 10, which was rated April 11, 1890, and the values of the constants in the resulting equation, $y=3.9897\ x+0.2986$, were used in computing the discharges. The observations were taken with meter at six tenths depth as the mean velocity at each velocity station, the length of time being generally 2 minutes.

E. L. Harman, assistant engineer, chief of party.

EXTRACT FROM REPORT OF MR. C. W. STURTEVANT, ASSISTANT ENGINEER, CHIEF OF PARTY, UPON FIELD WORK OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT PLUM POINT, MEMPHIS, AND HELENA, HIGH WATER 1890.

MEMPHIS, TENN., *December 12, 1890.*

* * * * * * *

The party was subsisted on the steamer *Abbot* and was composed of the following persons:

One assistant engineer in charge, 1 steam engineer, 1 steersman, 1 leadsman, 1 fireman, 3 deck hands, and 1 cook.

The meter used was a Price No. 8, and was suspended from the end of a one-fourth inch diameter steel sash cord, which was wound around a reel and paid out over a pulley on the end of a boom projecting 8 feet over the bow of the boat. An insulated return circuit wire was similarly attached alongside of the sash cord and wound around the same reel. As an 85-pound meter weight was used no guy lines were necessary.

Discharge observations were taken at Plum Point until the river came to a stand at its highest stage. The party then went to Memphis and took daily observations until the break in the levee at Austin, Miss., occurred. The party measured the discharge through the break, and then took observations at Helena until the high water had fallen several feet.

The river was out of its banks and the base lines for triangulation were measured with a transit and stadia board, except at Helena where the section and head signals were the same as used by the discharge party in winter of 1888 and 1889.

The details of the field work of a discharge observation are as follows:

The section sounded and the position of the boat located by the sextant at the moment of crossing the range.

The boat was then taken to the first velocity observation station, and the assistant engineer in charge taking a position on the roof (directly over the steam engineer and the throttle valve) with the sextant, an electric bell was placed on the bow of the boat with the button on the roof near the assistant engineer, the leadsman attending the register in the observation room at the bow of the boat.

When the boat was nearly up to the section the steersman signaled the engineer to slow down and hold the range with the throttle valve, and at the moment when the throttle valve was on range the assistant engineer would signal the leadsmen to start or stop the observation as the case might be, the meter being lowered six-tenths of the depth of water at that point, each observation lasting from 2 to 5 minutes. From twelve to fifteen velocity observations were taken at each section as per instructions. The field work would last from 3 to 5 hours, after which the tape was counted and the observation calculated.

* * * * * * *

Capt. S. W. ROESSLER,
Corps of Engineers, U. S. A.

EXTRACTS FROM REPORT OF MR. LOUIS E. RITTER, ASSISTANT ENGINEER, UPON FIELD WORK OF DISCHARGE OBSERVATIONS, MISSISSIPPI RIVER, AT HELENA, ARKANSAS.

AMELIA, ARK., *January 18, 1891.*

* * * * * * *

I have the honor to submit the following report on the field work of the low water discharge observations made at Helena, Ark., December, 1890.

The observations were made on a section about 2,300 feet below the section used in 1888-'89. This section was chosen as most convenient to the arrangement of the system of intersecting ranges used. These were erected on the bar on the Mississippi side of the river. No water flowed through behind the bar.

The ends of the section were marked by range signals, the one on the Arkansas side called "A," the one on the bar "B."

The distance from A to B was 3,485 feet.

A pivot signal was erected 6,447 feet above the section; a perpendicular from it to the section would pass through the point B. Between the pivot signal and the section, at an average distance of 1,900 feet from the pivot signal, the front signals were placed, the ranges formed by them and the pivot intersecting the section at intervals of 200 feet. The system of ranges was laid out by measuring two base lines, one 1,000 feet long and the other 2,000 feet, and measuring the necessary angles.

The minimum angle for locating a point on the section by means of these ranges was 62° 11′.

The apparatus used for measuring velocities consisted of Price meter No. 29, a register, relay, and seven zinc-carbon battery cells. The apparatus was operated from the steamer *Abbot.*

The meter was attached to a three-quarter inch iron rod, one end of which was fastened to a 50-pound lead weight and the other end to a three-sixteenths inch steel sash cord.

At the bow of the boat was a mast and boom derrick; the boom could be raised and lowered. At its lower end was attached a reel upon which were wound the steel cord supporting the meter weight, and two wires, one insulated, which made the circuit between the meter and the rest of the electrical apparatus. These wires and the sash cord passed over a pulley at the upper end of the boom, and down to the water.

Three cells were used on the meter circuit and 4 on the register circuit. A relay connected the two circuits.

The revolutions of the meter were recorded by means of the register in the usual manner and the time taken with a clock to the nearest second. The duration of an observation was from 250 to 300 seconds.

Soundings were taken at the velocity stations and half way between them; that is, at intervals of 100 feet. Near the ends of the section they were taken at intervals of 50 feet. In taking the soundings the boat was put onto range laterally and longitudinally by the steersman. An 8-pound lead was used and a three-eighth inch braided cotton line.

The river width each day was determined by measuring the distances of the water edges from the end signals.

In taking the velocities the boat was held on end laterally by the steersman and longitudinally by the engineer with the throttle. By an arrangement of signals between the steersman, engineer, and observer, the boat was always exactly on range at the time of starting and stopping an observation.

Before and after taking a set of discharge observations the gauge was read to the nearest hundredth of a foot, the lead line was tested, and the meter whirled to note any change that might have occurred.

* * * * * * *

One meter rating was made in still water on December 3, 1890, and another in running water on December 27, 1890.

* * * * * * *

Capt. S. W. ROESSLER,
Corps of Engineers, U. S. A.

*Results of discharge observations, Mississippi River, Plum Point Reach.**

Location.	Date.	Local gauge.	Fulton gauge.†	Rise or fall in preceding 24 hours.	Water area.	Maximum depth.	Width.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
	1890.	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*	
Main River	Mar. 7	30.30	32.8	+0.5	144,400	67	2,900	5.28	762,130	Calm.
Elmot Chute	Mar. 7	30.30	32.8		43,980	66	1,920	3.24	142,375	
Island No. 30 Chute	Mar. 7	30.30	32.8		33,310	28	1,345	3.39	113,012	
Total					221,690		6,165		1,017,517	
Main River	Mar. 9	30.90	33.6	+0.2	148,720	67	2,900	5.49	816,140	Light breeze across river.
Elmot Chute	Mar. 9	30.90	33.6		42,340	62	1,920	3.59	151,824	
Island No. 30 Chute	Mar. 9	30.90	33.6		34,564	29	1,345	3.16	109,393	
Total					225,624		6,165		1,077,357	
Main River	Mar. 12	31.66	34.2	+0.3	153,560	68	2,900	5.54	850,348	Upstream breeze; scattering drift.
Elmot Chute	Mar. 12	31.66	34.2		45,340	68	1,920	3.57	161,874	
Island No. 30 Chute	Mar. 12	31.66	34.2		34,460	30	1,345	3.39	116,868	
Total					233,360		6,165		1,129,090	
Main River	Mar. 15	32.09	34.7	+0.1	152,425	64	2,900	5.76	878,098	Light downstream breeze.
Elmot Chute	Mar. 15	32.09	34.7		49,615	67	1,920	3.52	174,689	
Island No. 30 Chute	Mar. 15	32.09	34.7		36,836	31	1,345	3.19	117,362	
Total					238,876		6,165		1,170,149	

* From reduction at office of first district engineer.

† Standard gauge.

*Results of discharge observations, Mississippi River, Memphis, Tenn.**

Date.	Standard gauge.	Rise or fall in preceding 24 hours.	Water area.	Maximum depth.	Width.	Mean velocity per second.	Discharge per second.	Direction and force of wind.
1890.	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*	
Mar. 17	35.60	0.0	159,632	107	2,850	8.36	1,335,187	Light breeze from bluffs.
18	35.50	0.0	154,394	107	2,851	8.24	1,272,922	Strong upstream breeze.
20	35.50	0.0	153,526	105	2,851	8.76	1,345,037	Moderate upstream wind.
22	35.65	0.0	144,792	109	2,851	8.51	1,232,445	Light upstream breeze.
24	35.58	0.0	151,479	107	2,851	8.69	1,315,857	Strong wind across river.
25	35.55	0.0	152,037	108	2,851	8.50	1,292,028	Calm.
26	35.46	—0.1	146,637	104	2,851	8.83	1,295,314	Light breeze in all directions.
27	35.40	—0.1	147,957	105	2,851	8.54	1,263,565	Light wind upstream.
29	35.30	0.0	152,232	96	2,851	8.46	1,288,566	Moderate upstream wind.
31	35.30	0.0	157,725	104	2,851	8.32	1,312,582	Light breeze after rain.
Apr. 1	35.38	+0.1	145,390	97	2,851	8.29	1,204,946	Calm.

*From reduction at office of Second District Engineer.

Results of discharge observations, Mississippi River, Helena, Ark.

Date.	Standard gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1890.	*Feet.*	*Feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cubic feet.*			
Apr. 3*	47.42	0.0	242,611				99.0	5,183		6.38	1,547,348	Upstream, strong		
4	47.40	−0.1	246,875				100.0	5,183		6.36	1,570,004	Moderate, downstream		
5	47.31	−0.1	236,125				93.0	5,183		6.36	1,500,843	Upstream		
7†	47.16	−0.1	236,315				94.0	5,183		6.18	1,460,675	Strong		
9	47.05	0.0	231,200				97.0	5,183		6.05	1,398,355	....do		
10	47.03	−0.1	238,800				96.0	5,183		5.88	1,405,100	Light, upstream		
12	47.08	0.0	235,505				93.0	5,183		6.13	1,443,430	Moderate, upstream		
14	47.20	+0.1	233,000				95.0	5,183		6.29	1,466,466	Calm		
16	47.40	+0.1	237,418				96.0	5,183		6.31	1,497,360	....do		
17	47.46	0.0	238,220				95.0	5,183		6.38	1,519,374	Downstream		
18	47.31	−0.1	238,720				97.0	5,183		6.23	1,487,103	Light breezes		
19	47.00	−0.2	228,890				94.0	5,182		6.43	1,471,400	....do		
21	46.00	−0.6	230,840				94.0	5,182		5.92	1,367,641	Northeast, moderate		
23	44.48	−0.8	224,090				92.0	5,181		5.66	1,269,101	Fog, calm		
Dec. 23	11.85	−0.6	63,990	63,990	32.4	32.4	51.5	1,975		3.852	246,464	VII. Light	9	22
24, a. m	11.17	−0.8	62,442	63,786	31.6	32.3	50.0	1,977	−204	3.830	239,163	III. Light	9	24
24, m	11.10	−0.8	62,990	64,472	31.9	32.6	50.5	1,977	+686	3.723	234,539		10	27
26	10.22	−0.3	60,331	63,534	30.9	32.2	49.0	1,955	−938	3.704	223,481	IX. Moderate	8	24
27	10.16	0.0	59,963	63,284	30.7	32.0	49.0	1,955	−250	3.815	‡238,573	XI. Strong	10	23

* Discharge through Austin crevasse April 3, 37,370 cubic feet per second.

† Discharge over bank, Louisville, New Orleans and Texas Railway April 7, 11,205 cubic feet per second.

‡ The recorded velocity at station 3 for this day seems abnormally high; interpolating a velocity for station 3 as observed on the 24th and 26th, the discharge for this day becomes 224,807 cubic feet per second.

NOTES.—Velocities were measured at six-tenths depth as mean velocity at each velocity station. The April results are from reduction at office of Second District Engineer; those for December are from reduction at office of the secretary. The method used in computing the discharges is the same as described in report accompanying results of observations at Carrollton, 1883 (M. R. C. pamphlet) except that in this case the length of the observations varying at the different stations, the notes were first reduced to registrations per second. For method used in computing areas see Report of Chief Engineers, 1887, page 2824. In the present case, however, there was but one sounding between two velocity stations. Other quantities in the table were found in the usual manner. Datum line taken at 11.85 feet, that being the gauge reading Dec. 23, 1890. The values of the constants for Price meter No. 29 from reduction in this office are: For Dec. 3, 1890, $a = 4.0795$, $b = +0.2966$; for Dec. 27, 1890, $a = 4.2263$, $b = +0.4295$. The results of these ratings were combined, giving weight to the values of a and b inversely as the squares of their mean errors in the two series, and the resulting equation $y = 4.1419\,x + 0.361$ was used in computing the December discharges.

*Results of discharge observations, Mississippi River, Arkansas City, Ark.**

Date.	Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Discharge outside of section.	Total discharge of river per second.
			Area.		Depth.			Width.					
	Reading.	Rise or fall in preceding 24 hours.	Water.	Below datum.†	Mean.	Mean datum.	Maximum.						
1890.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Mar. 14	48.2	+ 0.1	206,615	184,568	60.4	54.4	83.0	3,420	....	5.714	1,180,659	5,000	1,185,659
19	48.8	0.0	222,638	198,342	65.1	58.4	88.5	3,420	+ 13,774	6.335	1,410,441	8,000	1,418,441
25	49.2	+ 0.1	225,579	200,090	66.0	58.9	89.5	3,420	+ 1,748	5.364	1,210,124	10,000	1,220,124
26	49.4	+ 0.2	228,326	202,122	66.8	59.5	86.0	3,420	+ 2,032	5.685	1,298,010	10,000	1,308,010
28	49.2	− 0.2	218,791	193,167	64.0	56.9	89.0	3,420	− 8,955	5.544	1,212,919	10,000	1,222,919
30	48.8	− 0.2	231,870	207,211	67.7	61.0	92.0	3,420	+ 14,044	5.369	1,242,231	8,000	1,250,231
31	48.8	− 0.1	227,722	203,767	66.6	60.0	92.0	3,420	− 3,444	5.551	1,263,992	8,000	1,271,992
Apr. 2	48.6	− 0.1	230,119	206,675	67.3	60.9	89.0	3,420	+ 2,908	5.790	1,332,330	7,000	1,339,330
4	48.3	− 0.4	226,695	204,376	66.3	60.2	89.0	3,420	− 2,299	5.364	1,215,970	5,000	1,220,970
7	47.9	0.0	223,193	202,135	65.3	59.5	89.0	3,420	− 2,241	5.300	1,183,001	4,000	1,187,001
9	48.0	0.0	226,274	204,977	66.2	60.4	89.5	3,420	+ 2,842	5.373	1,215,849	4,000	1,219,849
11	47.9	− 0.1	233,503	212,479	68.3	62.6	88.0	3,420	+ 7,502	5.122	1,195,964	3,500	1,199,464
13	47.8	− 0.1	241,545	220,861	70.6	65.1	89.0	3,420	+ 8,382	5.513	1,331,745	3,000	1,334,745
15	47.8	0.0	237,359	216,846	69.4	63.9	91.0	3,420	− 4,015	5.398	1,281,250	3,000	1,284,250

* From reduction at office of Third District Engineer.
† The datum line is taken, as in former years, at 41.73 on the standard gauge, whose zero is 116.44 feet above the Cairo datum plane, survey Mississippi River.

NOTE.—The discharge section is at the same place as in 1889.

Results of discharge observations, Mississippi River, at Warrenton and Natchez, Miss., and Baton Rouge, La.

WARRENTON, MISS.

Date.	Gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Overflow.		Total discharge per second.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.				Area.	Discharge per second.	
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1890.	*Feet.*	*Feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cu. ft.*	*Sq. ft.*	*Cu. ft.*	*Cu. ft.*
Mch. 4	*46.3	0.0	196,594	†155,941	57.1	53.6	102.5	3,441	....	6.276	1,233,919	1,250	2,294	1,236,213
5	46.4	+0.1	196,304	155,334	57.0	53.4	102.0	3,441	— 607	6.286	1,234,027	1,320	2,336	1,236,363
6	46.5	+0.1	196,549	155,261	57.1	53.3	102.2	3,441	— 73	6.301	1,238,370	1,320	2,402	1,240,772
7	46.6	+0.1	197,416	155,810	57.4	53.5	104.0	3,441	+ 549	6.333	1,250,140	1,420	2,627	1,252,767
Apr. 11	47.7	+0.1	206,569	160,902	60.0	53.8	109.0	3,441	+5,092	6.823	1,306,077	1,760	3,274	1,309,351
12	47.9	+0.2	207,336	161,026	60.3	53.8	109.7	3,441	+ 124	6.371	1,320,905	1,920	3,571	1,324,476

NATCHEZ, MISS.

Date.	Reading.	Rise or fall.	Water.	Below datum.	Mean.	Mean datum.	Maximum.	Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Overflow area.	Overflow discharge per second.	Total discharge per second.
Mar. 17 a. m.	‡46.6	—0.2	147,106	....	69.8	....	118.0	2,108	....	9.355	1,376,181	....	....	....
17 p. m.	46.6	....	....	....	....	....	....	....	....	9.461	1,391,786	....	....	....

BATON ROUGE, LA.

Date.	Reading.	Rise or fall.	Water.	Below datum.	Mean.	Mean datum.	Maximum.	Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Overflow area.	Overflow discharge per second.	Total discharge per second.
Apr. 26	§35.8	—0.1	202,344	....	66.9	....	88.6	3,024	....	6.548	1,324,945	....	....	....

* Vicksburg standard gauge, zero 66.04 feet above Cairo datum plane, Survey Mississippi River.
† Datum line is taken same as in 1889, when the Vicksburg gauge read 33.5 feet.
‡ Standard gauge, zero 36.89 feet above Cairo datum plane, Survey Mississippi River.
§ Standard gauge, zero 20.06 feet above Cairo datum plane, Survey Mississippi River.

NOTES.—Velocity measurements made with the W. G. Price current meter at six-tenths depth as mean velocity at each velocity station. Velocity and sounding stations are coincident; at Warrenton 14 of each, Natchez 16, and Baton Rouge 9. At Warrenton and Baton Rouge, meter No. 22 was used; duration of an observation 2 minutes. Ratings of 1889 used in reduction, the equation being $y = 3.917\,x + 0.3114$. Warrenton discharge section at same place as in 1889. Mr. B. J. Oliveira, observer. At Natchez, meter No. 23 was used; duration of an observation 3 minutes. Rating of March 8, 1890, used in reduction. W. G. Price, assistant engineer, in charge of field work. Methods of computation same as described in Mississippi River Commission pamphlet of results of 1889 observations.

Results of discharge observations, Mississippi River, Red River Landing, La.

Date.	Red River Landing gauge		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Overflow.		Total discharge per second.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.				Area.	Discharge per second.	
			Water.	Below datum.*	Mean.	Meam datum.	Maximum.							
1890.	*Feet.*	*Feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cu. ft.*	*Sq. ft.*	*Cu. ft.*	*Cu. ft.*
Feb. 21	41.8	+0.2	191,917	218,485	49.0	54.3	76.8	3,915	....	....	....	....	....	....
22	41.8	0.0	196,342	222,832	50.2	55.4	79.4	3,915	+ 4,347	5.253	1,031,413	....	....	1,031,413
23†	41.8	0.0	195,970	222,303	50.1	55.2	....	3,915	— 529	5.185	1,016,186	....	....	1,016,186
24	41.9	+0.1	195,374	221,472	49.9	55.0	79.7	3,915	— 831	5.252	1,026,103	....	....	1,026,103
26	42.3	+0.2	198,613	223,258	50.7	55.5	79.2	3,915	+ 1,786	5.157	1,024,176	....	....	1,024,176
27†	42.3	0.0	197,949	222,359	50.6	55.2	....	3,915	— 899	5.151	1,023,021	....	....	1,023,021
28	42.6	+0.3	197,937	221,372	50.5	55.0	80.2	3,920	— 987	5.238	1,036,698	....	....	1,036,698
Mar. 3	42.6	0.0	201,492	224,730	51.4	55.8	80.0	3,920	+ 3,358	5.177	1,043,221	....	....	1,043,221
18‡	44.9	0.0	209,112	223,593	53.1	55.6	81.5	3,935	— 1,137	5.425	1,134,368	....	....	1,134,368
28	44.8	0.0	210,538	225,719	52.8	56.1	80.8	3,989	+ 2,126	5.291	1,113,896	1,616	3,520	1,117,416
Apr. 1	44.9	+0.2	213,941	228 523	53.6	56.8	81.7	3,989	+ 2,804	5.221	1,117,033	1,616	3,520	1,120,553
8	46.0	+0.2	216,561	226,740	54.3	56.3	83.6	3,990	— 1,783	5.454	1,181,017	1,616	3,520	1,184,537
12	46.7	+0.1	217,403	224,607	54.0	55.8	81.9	4,024	— 2,133	5.587	1,214,711	1,616	3,520	1,218,231
16	47.4	+0.2	218,940	223,287	54.4	55.5	82.5	4,025	— 1,320	5.696	1,247,059	7,576	12,671	1,259,730
18	47.8	+0.3	221,027	223,683	54.9	55.6	82.5	4,025	+ 396	5.759	1,272,989	9,725	10,302	1,283,291
May 1	47.4	—0.1	231,367	235,875	57.5	58.6	77.2	4,025	+12,192	6.086	1,408,030	9,995	9,902	1,417,932
7	47.2	—0.1	232,531	237,925	57.8	59.1	82.3	4,025	+ 2,050	6.190	1,439,300	8,283	13,210	1,452,510
10	46.9	—0.1	234,210	240,809	58.2	59.8	80.1	4,023	+ 2,884	5.791	1,356,411	7,594	8,572	1,364,983
13	46.6	—0.1	228,104	235,588	56.7	58.5	79.5	4,022	— 5,221	5.875	1,339,997	7,935	10,621	1,350,618
15	46.5	—0.1	233,271	241,358	58.0	60.0	82.4	4,022	+ 5,770	5.769	1,345,734	7,535	10,266	1,356,000
20	46.0	—0.1	228,221	236,269	57.3	58.7	82.4	3,950	— 5,089	5.738	1,298,068	2,919	6,290	1,304,358

* Datum line taken same as in former series at 48.50 feet on the standard gauge, whose zero is 23.85 feet above the Cairo datum plane, Survey Mississippi River. † Soundings interpolated. ‡ Water rough.

NOTES.—Discharge section at same place as in 1884-'85 and 1889. Current observations taken with Price meter No. 23, at six-tenths depth as the mean velocity at each velocity station; length of time generally 3 minutes. Velocity and sounding stations are coincident; 21 velocity stations, and 21 and 22 sounding stations. W. G. Price, assistant engineer, in charge of field work. The results of meter rating observations of March 8, 1890, $y = 3.9515\,x + 0.393$, used. Methods of computation same as described in Mississippi River Commission pamphlet of results of 1889 observations.

Results of discharge observations, Atchafalaya River, at Simmsport, La., and Bayou La Fourche, at Donaldsonville, La.

SIMMSPORT, LOUISIANA.

Date.	Simmsport gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area. Water.	Area. Below datum.	Depth. Mean.	Depth. Mean datum.	Depth. Maximum.	Width.						
1890.	*Feet.*	*Feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cu. ft.*			
Mar. 6	40.3	+0.1	50,493	43,329	55.7	49.0	88.1	906	....	4.307	217,490	....		
19	42.9	+0.1	54,339	44,654	57.9	50.5	92.6	939	+1,325	4.962	269,609	....		
27	43.0	0.0	53,897	44,184	57.4	49.9	91.6	939	− 470	4.918	264,780	Upstream strong		
Apr. 7	44.2	+0.2	57,508	46,550	60.6	52.6	93.0	949	+2,366	5.331	306,594	....		
10	44.8	+0.2	58,287	46,818	61.4	52.9	93.9	950	+ 268	5.756	335,503	....		
11	44.9	+0.1	61,880	50,320	65.1	56.9	102.2	950	+3,502	6.040	373,742	....		
15	44.9	0.0	60,147	48,587	63.3	54.9	98.6	950	−1,733	6.682	401,927	....		
17	45.2	+0.1	59,147	47,338	62.1	53.5	103.2	953	−1,249	6.804	402,411	....	10	10
May 6	44.8	−0.1	63,258	51,731	66.4	58.5	100.0	952	+4,393	7.485	473,493	....		
8	44.7	−0.1	63,364	51,981	66.6	58.7	105.3	951	+ 250	7.449	472,018	....		
12	44.4	−0.1	64,291	53,143	67.7	60.0	105.2	950	+1,162	7.465	479,908	....		
14	44.3	−0.1	63,889	52,906	67.7	59.8	109.4	944	− 237	7.058	450,927	....		
17	44.1	−0.1	62,178	51,348	65.7	58.0	105.0	946	−1,558	7.032	437,209	....		
19	44.0	−0.1	63,007	52,307	66.7	59.1	105.0	944	+ 959	7.096	447,098	....		
BAYOU LA FOURCHE, DONALDSONVILLE, LOUISIANA.														
Feb. 21	....	....	4,885	....	19.2	....	30.0	255	....	6.020	32,340	Calm	8	1

NOTES.—Velocity measurements made with W. G. Price current meters, at six-tenths depth as the mean velocity at each velocity station. At Simmsport, the discharge section is at same place as in 1889, and datum line taken same as in that series at 32.30 feet on the Simmsport gauge. Observations made with meter No. 23, the duration being generally 3 minutes at each station; the results of rating of March 8, 1890, were used in the reduction. W. G. Price, assistant engineer, in charge of field work. At Donaldsonville, observations made with meter No. 25, the duration being 2 minutes at each station; the results of rating of December 13, 1889, were used in the reduction. Mr. B. J. Oliveira, observer. Methods of computation same as described in Mississippi River Commission pamphlet of results of 1889 observations.

Results of discharge observations, Mississippi River, Carrollton, La.

Date.	Standard gauge. Reading.	Standard gauge. Rise or fall in the preceding 24 hours.	Cross section of discharge. Area. Water.	Cross section of discharge. Area. Below datum.	Cross section of discharge. Depth. Mean.	Cross section of discharge. Depth. Mean datum.	Cross section of discharge. Depth. Maximum.	Cross section of discharge. Width.	Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
1890.	Feet.	Feet.	Sq. ft.	Sq. ft.	Feet.	Feet.	Feet.	Feet.	Sq. ft.	Feet.	Cu. ft.			
Feb. 26	* ‡ 14.7	0.0	193,675	190,868	80.0	78.9	114.0	2,420	....	7.343	1,422,060	South		
27	* † 14.8	+0.1	192,031	188,982	79.4	78.1	113.0	2,420	— 1,886	6.719	1,290,294	South. High		
28	* 15.1	+0.3	195,422	191,647	80.8	79.2	114.4	2,420	+ 2,665	7.143	1,395,805	North. High		
Mar. 1	14.8	—0.3	194,326	191,277	80.3	79.0	112.5	2,420	— 870	6.527	1,268,434	....		
3	15.0	0.0	178,865	175,453	73.9	72.5	114.0	2,420	—15,824	6.547	1,170,949	Calm		
4	14.9	—0.1	179,090	175,799	74.0	72.6	106.5	2,420	+ 346	6.200	1,110,325	....do		
5	15.0	+0.1	180,896	177,242	74.8	73.2	106.2	2,420	+ 1,448	6.[illegible]62	1,150,876	SW. Light		
6	15.2	+0.2	179,080	174,942	74.0	72.3	107.0	2,420	— 2,800	6.562	1,175,142	N. Light		
7	15.2	0.0	175,240	171,102	72.4	70.7	105.5	2,420	— 3,840	6.439	1,128,306	NE. Light		
8	15.2	0.0	172,054	167,916	71.1	69.4	113.0	2,420	— 3,186	6.777	1,165,997	N. Light		
10	15.4	+0.1	186,218	181,717	76.9	75.1	112.0	2,420	+13,801	6.874	1,280,040	ENE. Light		
11	‡ 15.4	0.0	185,172	180,671	76.5	74.7	112.2	2,420	— 1,046	6.179	1,144,188	SE. Strong		
12	15.4	0.0	184,462	179,961	76.2	74.4	112.9	2,420	— 710	6.238	1,150,598	....do		
14	16.0	+0.1	187,130	181,298	77.3	74.9	113.1	2,420	+ 1,337	6.902	1,291,617	N		
18	15.9	—0.1	186,839	181,128	77.2	74.8	112.0	2,420	— 170	6.441	1,203,472	S		
19	15.9	0.0	186,008	180,387	76.9	74.5	114.0	2,420	— 741	6.680	1,243,104	SW		
20	15.8	—0.1	188,683	183,093	78.0	75.7	112.3	2,420	+ 2,706	6.747	1,273,074	S. Heavy		
21	15.9	+0.1	191,724	186,013	79.2	76.9	113.7	2,420	— 2,920	6.225	1,193,487	S. Very strong	15	15
22	15.9	0.0	188,841	183,130	78.0	75.7	117.0	2,420	— 2,883	5.952	1,124,053	Calm		
24	15.6	—0.1	192,557	187,572	79.6	77.5	112.5	2,420	— 4,442	6.002	1,155,708	SE		
25	15.5	—0.1	191,293	186,550	79.0	77.1	112.5	2,420	— 1,022	6.112	1,169,111	N., SW., NE		
26	15.4	—0.1	189,062	184,561	78.1	76.3	113.5	2,420	— 1,989	6.225	1,176,884	N		
28	15.5	—0.1	184,618	179,875	76.3	74.3	110.0	2,420	— 4,686	5.989	1,105,759	N. Strong		
29	15.2	—0.3	181,398	177,381	75.0	73.3	116.5	2,420	— 2,494	5.913	1,072,669	ENE		
31	15.2	—0.1	182,575	178,679	75.4	73.8	117.9	2,420	— 1,298	5.926	1,081,964	S		
Apr. 1	15.1	—0.1	181,120	177,345	74.8	73.3	115.0	2,420	— 1,334	5.902	1,068,925	ENE		
2	15.2	+0.1	179,907	175,769	74.3	72.6	111.2	2,420	— 1,576	5.921	1,065,225	E		
3	§ 15.6	+0.4	181,514	176,650	75.0	73.0	....	2,420	— 881	6.093	1,106,028	NW		
4	15.4	—0.2	182,005	177,625	75.2	73.4	116.7	2,420	— 975	6.002	1,092,400	NNW. Strong		
5	15.3	—0.1	182,056	177,797	75.2	73.5	113.8	2,420	— 172	6.051	1,101,645	NE		
7	15.3	—0.1	182,447	178,188	75.4	73.6	112.8	2,420	— 391	6.010	1,096,425	S		
8	15.2	—0.1	182,069	178,052	75.2	73.6	113.0	2,420	— 136	5.995	1,091,429	SSW		
9	15.2	0.0	179,136	175,119	74.0	72.4	112.8	2,420	— 2,933	5.954	1,066,586	....do.		
10	15.1	—0.1	179,943	176,168	74.4	72.8	115.0	2,420	+ 1,049	5.906	1,062,749	NNW. Strong		
11	15.0	—0.1	178,853	175,199	73.9	72.4	114.2	2,420	— 969	5.723	1,023,542	SE		

* Chief of party considered observations unreliable on account of inexperienced men. † Water rough. ‡ Water very rough. § Soundings interpolated.

Results of discharge observations, Mississippi River, Carrollton, La.—Continued.

Date.	Standard gauge.		Cross section of discharge.						Scour or fill.	Mean velocity per second.	Discharge per second.	Direction and force of wind.	No. of velocity stations.	No. of soundings.
	Reading.	Rise or fall in the preceding 24 hours.	Area.		Depth.			Width.						
			Water.	Below datum.	Mean.	Mean datum.	Maximum.							
1890.	*Feet.*	*Feet.*	*Sq. ft.*	*Sq. ft.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. ft.*	*Feet.*	*Cu. ft.*			
Apr. 12	15.0	0.0	180,018	176,606	74.4	73.0	113.0	2,420	+1,407	5.746	1,034,335	S. E.	15	15
14	15.0	0.0	179,791	176,137	74.3	72.8	112.0	2,420	− 469	5.677	1,020,687	S. Light		
15	15.0	0.0	180,037	176,625	74.4	73.0	112.8	2,420	+ 488	5.645	1,016,371	SW. light		
16	15.0	0.0	181,560	177,906	75.0	73.5	114.0	2,420	+1,281	5.580	1,013,174	SW		
28	14.0	−0.1	182,166	181,053	75.3	74.8	112.2	2,420	+3,147	5.486	999,433	NNW		
29	14.0	0.0	181,184	180,071	74.9	74.4	113.8	2,420	− 982	5.422	982,456	NNW		
30	14.0	0.0	180,579	179,587	74.6	74.2	111.4	2,420	− 484	5.363	968,471	N		
May 1	13.8	−0.2	179,331	178,702	74.1	73.8	112.0	2,420	− 885	5.473	981,404	NW. light		
6	13.7	−0.2	177,628	177,241	73.4	73.2	110.0	2,420	−1,461	5.211	925,659	N		
14	13.4	+0.1	178,650	178,868	73.8	73.9	109.0	2,429	+1,627	5.137	917,653	SE		

NOTES.—Discharge section at same place as in 1889. Current measurements made with Price meter No. 25, at six-tenths depth as the mean velocity at each velocity station; duration generally 2 minutes at each station. The results of meter rating observations of December 13, 1889, $y = 3.99x + 0.395$, used. Datum line taken same as in 1889 at 13.54 feet on the standard gauge, whose zero is 20.91 feet above the Cairo datum plane, Survey Mississippi River. Mr. B. J. Oliveira, observer. Methods of computation same as descrided in Mississippi River Commission pamphlet of results of 1889 observations.

*Crevasse measurements in vicinity of Arkansas City, Ark., 1890.**

Decription of crevasse.	Locality on inch to mile map.	Discharge section.	Width.	Area.	Mean velocity per second.	Discharge per second.	Date of observation.	Method used.	Date of crevasse.	Remarks.
	Miles.		*Feet.*	*Sq. feet.*	*Feet.*	*Cu. feet.*				
Brooksfield Opossum Fork Levee		R. B.	590	6,404	4.00	25,622	Apr. 19	Surface floats	Mar. 27	Maximum discharge April 8=38,000 cubic feet.
Boggy Bayou	426	R. B.	273	10,860	2.44	26,489	Apr. 19	...do	Apr. 5	Maximum discharge April 9=44,000 cubic feet.
Sappington	429	R. B.	620	5,118	3.58	18,321	Apr. 17	...do	Mar. 9	Maximum discharge March 12=35,000 cubic feet.
Ferguson	426	R. B.	320	3,468	4.03	13,987	Apr. 17	...do	Mar. 27	Maximum discharge March 31=17,000 cubic feet.
Chicot	431.5	R. B.	240	1,700	4.85	8,241	Apr. 17	...do	Mar. 27	Maximum discharge March 27=10,000 cubic feet.
Between Chicot and Arkansas City.	433	R. B.	354	2,480	5.84	14,483	Mar. 25	...do	Mar. 24	Maximum discharge March 26=17,000 cubic feet.
Do		R. B.	390	3,046	0.95	−2,901	Apr. 17	...do	Mar. 24	Commenced flowing into river March 28.
Drainage openings and crevasses between Arkansas City and Trippe.		R. B.	16,180	111,013	1.24	187,500	Apr. 7–8	...do		Maximum discharge April 10=148,600 cubic feet.
Do		R. B.	16,190	111,266	1.34	148,591	Apr. 9–10	...do		
Do		R. B.	15,000	106,162	1.32	140,558	Apr. 14–16	...do		
Catfish	432	L. B.	1,718	36,257	5.73	207,851	Apr. 6	Meter	Apr. 4	Maximum discharge April 6=208,000 cubic feet.
Do		L. B.	1,969	43,281	4.72	204,500	Apr. 11	...do	Apr. 4	
Do		L. B.	1,969	43,011	4.72	203,173	Apr. 13	...do	Apr. 4	
Lower side of Catfish	431	L. B.	3,097	51,980	2.09	−108,647	Apr. 11–13	Surface floats	Apr. 4–5	Flowing into river. Maximum discharge April 21=114,000 cubic feet.
Do	432	L. B.	3,428	54,632	2.09	−114,000		...do		
Easton	435.2	L. B.	750	41,000	1.35	55,296	Apr. 4	...do	Mar. 28	Maximum discharge April 13=68,000 cubic feet. Area of section sounded below crevasse=29,739 square feet. Above crevasse=21,581 square feet.
Do	435.2	L. B.	776	41,000	1.43	58,752	Apr. 11	...do	Mar. 28	
Do	435.2	L. B.	780	41,000	1.65	67,650	Apr. 13	...do	Mar. 28	
Huntington	438.5	L. B.	625	24,789	4.46	110,513	Apr. 10	Meter	Mar. 28	Maximum discharge April 1=125,000 cubic feet. Commenced flowing into river April 1.
Do	438.5	L. B.	625	23,099	4.31	99,513	Apr. 11	...do	Mar. 28	
Do	438.5	L. B.	625	21,376	4.36	93,244	Apr. 13	...do	Mar. 28	

* From reduction at office of third district engineer.

*Crevasse measurements, third district, below Arkansas City, Ark., 1890.**

Description of crevasse.	Locality on inch to mile map.	Discharge section.	Width.	Area.	Mean velocity per second.	Discharge per second.	Date of observation.	Method used.	Date of crevasse.	Remarks.
	Miles.		*Feet.*	*Sq. feet.*	*Feet.*	*Cu. feet.*				
Offutt	444.5	L. B.	860	37,467	−0.87	−13,692	Apr. 15	Surface velocity.	Mar. 18	Maximum discharge March 21=35,000 cubic feet. Flowing into river after April 1.
Luna	467	R. B.	425	2,975	10.4	30,940	Mar. 19	Surface floats.	Mar. 18	Measured by A. F. Kilpatrick. Maximum discharge March 19=31,000 cubic feet.
Do	467	R. B.	550	3,850	8.0	30,800	Mar. 22	do	Mar. 18, 7 a. m.	
Do	467	R. B.	625	4,062	7.2	29,246	Mar. 25	do	do	
Do	467	R. B.	630	4,095	7.2	29,484	Mar. 26	do	do	
Do	467	R. B.	730	4,380	6.0	26,280	Apr. 1	do	do	
Do	467	R. B.	750	4,125	6.0	24,744	Apr. 4	do	do	
Do	467	R. B.	760	4,180	5.6	23,408	Apr. 5	do	do	
Do	467	R. B.	760	3,800	5.2	19,760	Apr. 7	do	do	
Do	467	R. B.	760	3,800	4.8	18,240	Apr. 8	do	do	
Do	467	R. B.	765	3,825	4.8	18,360	Apr. 9	do	do	
Do	467	R. B.	765	3,825	4.4	16,829	Apr. 10	do	do	
Do	467	R. B.	770	3,850	4.4	16,940	Apr. 11	do	do	
Do	467	R. B.	770	3,850	4.0	15,400	Apr. 12	do	do	
Do	467	R. B.	775	3,875	3.5	13,640	Apr. 14	do	do	
Do	467	R. B.	775	3,720	3.4	12,499	Apr. 15	do	do	
Columbia and Point Chicot	470	R. B.	5,600	25,725	1.28	33,034	Mar. 31	do	Mar. 28, 4 a. m.	Maximum discharge April 3=35,200 cubic feet.
Do	470	R. B.	5,850	26,905	1.31	35,214	Apr. 3	do	do	
Do	470	R. B.	5,850	27,655	1.24	34,402	Apr. 4	do	do	
Do	470	R. B.	5,850	26,480	1.21	31,964	Apr. 5	do	do	
Do	470	R. B.	5,850	26,130	1.27	33,144	Apr. 7	do	do	
Do	470	R. B.	5,850	25,710	1.11	28,515	Apr. 11	do	do	
Do	470	R. B.	5,850	24,170	1.01	24,464	Apr. 14	do	do	
Do	470	R. B.	5,850	25,380	0.98	24,947	Apr. 15	do	do	
Point Chicot	472	R. B.	2,940	6,615	0.92	6,055	Mar. 12	do	Mar. 7	Discharging into river.
Miller Bend	474	L. B.	300						Apr. 7	Maximum discharge April 15=10,000 cubic feet (estimated).
Skipwith	530	L. B.	1,020	34,118	1.87	63,704	Apr. 2	Meter	Mar. 26	Measured by F. P. Spalding, U. S. surveyor.
Do	530	L. B.	1,100	39,525	2.10	82,870	Apr. 5	do	do	
Do	530	L. B.	1,210	39,684	1.88	74,480	Apr. 9	do	do	
Do	530	L. B.	1,240	40,424	1.92	77,648	Apr. 14	do	do	
Do	530	L. B.	1,240	41,875	1.77	74,188	Apr. 16	do	do	
Do	530	L. B.	1,240	41,014	1.55	63,477	Apr. 19	do	do	
Do	530	L. B.	1,260	42,508	1.67	70,954	Apr. 24	do	do	
Do	530	L. B.	1,260	42,210	1.52	64,210	Apr. 28	do	do	
Do	530	L. B.	1,260	39,970	1.06	42,487	May 1	do	do	
Do	530	L. B.	1,260	38,728	1.00	38,566	May 6	do	do	

* From reduction at office of third district engineer, except Skipwith, which was recomputed at secretary's office.

*Crevasse measurements in fourth Mississippi River district, 1890.**

Description of crevasse.	Locality on inch to mile map.	Discharge section.	Width.	Area.	Mean velocity per second.	Discharge per second.	Date of observation.	Method used.	Date of crevasse.	Remarks.
	Miles.		*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*				
Lake Concordia	602	R. B.	837	11,174	4.21	47,042	May 10	Log line	Apr. 22	
Arnauldia	701¼	R. B.	455	1,101	1.70	1,871	May 11	do	Apr. 23	
Henderson-Ashley	711⅜	R. B.	878	6,783	5.00	33,916	May 12	Surface floats	Apr. 23	
Racourci	770	R. B.	380	1,254	4.32	5,417	May 22	do	Apr. 23	Closed May 28.
Upper Morganza	788¾	R. B.	790	6,320	5.00	31,600	May 22	do	Apr. 21	
New Morganza	789¼	R. B.	2,543	33,357	4.38	146,034	May 22	do	Apr. 22	
Sneed	792¼	R. B.	147	523	6.00	3,139	May 22	do	Apr. 21	
Lanaux	792¾	R. B.	151	453	6.72	3,044	May 22	do	Apr. 21	
Fanny Riche	794¼	R. B.	845	6,228	4.35	27,118	May 22	do	Apr. 21	
Preston	801⅝	R. B.	213	980			May 23	do	Apr. 21	
Taylor No. 1	802¼	R. B.	203	690			May 23	do	Apr. 20	Closed May 17.
Taylor No. 2	806¼	R. B.	51	189			May 23	do	Apr. 20	Closed May 11.
Point Manoir	809	R. B.	571	1,610			May 23	do	Apr. 30	Do.
Lobdell	816¼	R. B.	1,981	14,303	4.12	58,892	May 23	do	Apr. 22	Closed May 17.
Martines	842¾	L. B.	124	2,443			May 23	do	Apr. 22	Closed April 28.
Nita	899	L. B.	2,892	43,380	9.28	402,556	May 23	do	Mar. 14	
Corinne No. 1	973¼	L. B.	25						Feb. 13	Closed February 15.
Corinne No. 2	973½	L. B.	30						Mar. 26	Closed March 26.
Corinne No. 3	973¾	L. B.	25						Mar. 26	Do.
Bertranville	990½	L. B.	15						Feb. 23	Closed February 23.
Live Oak	991½	R. B.	116	754	7.75	5,881	Mar. 26	Surface floats	Mar. 20	Closed April 10.
Woodland	992¾	L. B.	10						Mar. 22	Closed March 22.
Myrtle Grove No. 1	999⅓	R. B.	540	2,970	2.18	6,474	May 6	Surface floats	Mar. 21	
Myrtle Grove No. 2	999½	R. B.	295	1,032	5.00	5,153	May 6	do	Mar. 21	
St. Sophie No. 1	1,000½	L. B.	75						Feb. 13	Closed February 15.
St. Sophie No. 2	1,000½	L. B.	70						Mar. 4	Closed March 10.
St. Sophie No. 3	1,000½	L. B.	15						Mar. 7	Closed March 9.
St. Sophie No. 4	1,000½	L. B.	54	648	10.00	6,480	Apr. 23	Surface floats	Apr. 21	Closed April 30.
St. Sophie No. 5	1,000½	L. B.	22	198	10.00	1,980	Apr. 23	do	Apr. 21	Do.
St. Sophie No. 6	1,000½	L. B.	71	639	10.00	6,390	Apr. 23	do	Apr. 21	Do.
St. Sophie No. 7	1,000½	L. B.	50	300	10.00	3,000	Apr. 23	do	Apr. 21	Do.
St. Sophie No. 8	1,000½	L. B.	21	105	10.00	1,050	Apr. 23	do	Apr. 21	Do.
St. Sophie No. 9	1,000½	L. B.	40	220	10.00	2,200	Apr. 23	do	Apr. 21	Do.
St. Sophie No. 10	1,000½	L. B.	38	181	9.42	1,705	Apr. 23	do	Apr. 21	Do.
Harlem No. 1	1,003½	L. B.	50	400	10.78	4,312	Mar. 23	do	Mar. 21	Closed March 25.
Harlem No. 2	1,003½	L. B.	10						Mar. 26	Closed March 27.
Harlem No. 3	1,003½	L. B.	15						May 10	Closed May 11.
Thibaut No. 1	1,008½	L. B.	10						Apr. 21	Closed April 22.
Thibaut No. 2	1,008½	L. B.	12						Apr. 21	Do.
Empire Mills No. 1	1,012½	L. B.	15						Mar. 14	Closed March 14.

* From reduction at office of fourth district engineer.

Crevasse measurements in fourth Mississippi River district, 1890—*Continued.

Description of crevasse.	Locality on inch to mile map.	Discharge section.	Width.	Area.	Mean velocity per second.	Discharge per second.	Date of observation.	Method used.	Date of crevasse.	Remarks.
	Miles.		*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*				
Empire Mills No. 2	$1,012\frac{1}{8}$	L. B.	15						Mar. 26	Closed March 26.
Bohemia No. 1	$1,015\frac{1}{8}$	L. B.	30 to 50						Mar. 19	Closed March 20.
Bohemia No. 2	$1,015\frac{1}{8}$	L. B.	6						Mar. 28	Closed March 28.
Bohemia No. 3	$1,015\frac{1}{8}$	L. B.	10						Mar. 28	Do.
Riceland	1,017	R. B.	60						Apr. 19	Closed April 25.
New Texas Landing	$1,020\frac{1}{8}$	L. B.	30						Feb. 24	Closed February 28.

*From reduction at office of fourth district engineer.

*Results of discharge observations, St. Francis Basin.**

Station.	Date.	Memphis gauge.	Area.	Mean velocity per second.	Discharge per second.
	1890.	*Feet.*	*Sq. feet.*	*Feet.*	*Cubic feet.*
Kansas City, Springfield and Memphis Rwy	Mar. 17, 18, 19	35.60	264,994	1.84	487,536
Do	Mar. 28, 29	35.50	274,020	1.77	484,111
St. Louis, Iron Mountain and Southern Rwy	Mar. 21, 22	35.40	498,250	1.16	578,817
Little Rock and Memphis Rwy	Apr. 1, 3	35.40	229,551	2.18	501,225

*Extract from annual report of Captain Leach, 1890.

APPENDIX C 7.

High-water marks of 1890, Mississippi River, Cairo, Ill., to Carrollton, La.

Station.	Bank.	Distance from Cairo.	Elevation above Cairo, datum plane.	Distance between high-water marks.	Fall between high-water marks.	Slope per mile.	U. S. gauge reading.	Date of high water.	Authority for high water.	Remarks.
		Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*			
Cairo, Ill	L.	0.0	339.64				48.80	Mar. 12	United States gauge	
Belmont, Mo	R.	21.3	330.17	21.3	9.47	.445	43.03	Apr. 6	do	
New Madrid (Morrisson Landing), Mo.	R.	69.0	313.95	47.7	16.22	.340	38.15	Mar. 15	do	
Tiptonville, Tenn	L.	85.4	306.31	16.4	7.64	.466			E. L. Harman	
Gayoso, Mo	R.	105.7	295.78	20.3	10.53	.519		Mar. 14	G. W. Carleton	
Caruthersville, Mo	R.	110.0	292.66	4.3	3.12	.726		Mar. 14	W. A. Joplin	
Mitchell Point, Tenn	L.	122.3	287.10?	12.3	5.56	.452		Mar. 21	H. D. Thompson	
Cottonwood Point, Mo	R.	123.3	287.02	1.0	.08	.080	36.40	Mar. 15–16	United States gauge	
Hickman Landing, Ark	R.	131.3	285.99?	8.0	1.03	.129		Mar. 14	George Buckner	Compared with adjacent stations, this seems too high.
Island 26		148.2?	276.1					Mar. 18	W. R. Warren	This elevation is obtained from reference to high-water mark 1887. If the reference to high-water of 1882 is accepted elevation would be 276.75. Distance approximate.
Wards Landing, Ark	R.	148.2	276.0	16.9	9.99	.591		Mar. 12	W. W. Ward	
Daniels Point, Ark	R.	152.0	273.8	3.8	2.2	.579			First district engineer	
Gold Dust, Tenn	L.	156.6	272.2	4.6	1.6	.348			do	
Fletcher Landing, Ark	R.	158.1	271.3	1.5	0.9	.600			do	
Elmot Landing, Ark	R.	160.8	270.2	2.7	1.1	.407			do	
Plum Point, Tenn	L.	164.2	269.4	3.4	0.8	.235			do	
Yankee Bar		169.5	267.2	5.3	2.2	.415			do	
Cold Creek, Tenn	L.	172.0	266.6	2.5	0.6	.240			do	
Fulton, Tenn	L.	175.4	263.45	3.4	3.15	.923	34.90	Mar. 22	United States gauge	
Memphis, Tenn	L.	230.0	239.57	54.6	23.88	.437	35.60	Mar. 23–24. Apr. 4 to 5.	do	
Mhoon Landing, Miss	L.	275.9	219.98	45.9	19.59	.427	38.50	Mar. 28 to Apr. 2.	United States gauge	
Helena, Ark	R.	306.5	209.70	30.6	10.28	.336	47.72	Mar. 29 to 30.	do	
Westover Landing, Ark	R.	318.8	203.68	12.3	6.02	.489		Mar. 29	H. C. Robb	
Sunflower Landing, Miss	L.	352.7	189.98	33.9	13.70	.404	42.90	Mar. 30 to Apr. 1.	United States gauge	
Bolivar County line, Miss	L.	365.7	186.30						Third district engineer*	

* Elevation scaled from profile furnished by third district engineer.

High-water marks of 1890, Mississippi River, Cairo, Ill., to Carrollton, La.—Continued.

Station.	Bank.	Distance from Cairo.	Elevation above Cairo datum plane.	Distance between high-water marks.	Fall between high-water marks.	Slope per mile.	U. S. gauge reading.	Date of high water.	Authority for high water.	Remarks.
		Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*			
Beith Point, Ark	R.	366.6	186.33	13.9	3.65	.263		Apr. 30	R. H. Beith	
Australia, Miss	L.	370.0	186.13	3.4	0.20	.059			William Starling	
Concordia, Miss	L.	378.0	183.94	8.0	2.19	.274			do	
Do.	L.	378.0	183.1						Third district engineer *	
Angle at Victoria, Miss	L.	390.0?	182.03	12.0	1.91	.159			William Starling	
Opposite mouth of White River.	L.	393.2?	180.1						Third district engineer *	
Mouth of White River, Ark	R.	393.2	179.13	3.2	2.90	.906	50.40	Mar. 31	United States gauge	
Terrene, Miss	L.	394.2	178.74	1.0	0.39	.390			William Starling	
Head of Island 73	R.	396.5	178.83	2.3	—0.09	—.039			Third district engineer	
Rosedale, Miss	L.	398.2	178.1	1.7	0.73	.429			do *	
Riverton, Miss	L.	399.0	177.62	0.8	0.48	.600			William Starling	
Mouth of Knowlton Bayou	R.	400.0	176.83	1.0	0.79	.790			Third district engineer	
Mouth of Arkansas River	R.	401.6	176.03	1.6	0.80	.500			do	
Ozark Bend	R.	408.0	174.73	6.4	1.30	.203			do	
Caulk Point, Ark	R.	413.5	173.23	5.5	1.50	.273			do	
Nibletts, Miss	L.	414.7	173.6	1.2	—0.37	—.308			do *	
Storms, Miss	L.	416.0	173.6	1.3	0.0	.000			do *	
Bolivar, Miss	L.	416.8	173.1	0.8	0.50	.625			do *	
Kentucky Landing	L.	418.6	172.1	1.8	1.00	.556			do *	
Good Luck Landing, Ark	R.	423.3	171.33	4.7	0.77	.164			do	
Dr. Rowlands, Miss	L.	424.0	170.2	0.7	1.13	1.614			Third district engineer *	
Lucca Landing, Ark	R.	427.2	169.6	3.2	0.60	.188			do*	Table received in 1891 makes this 170.44.
Chicot City, Ark	R.	431.6	167.7?	4.4	1.90	.432			do*	Table received in 1891 makes this 168.74.
Mound Landing, Miss	L.	435.5	167.6	3.9	0.10	.026			William Starling	
Arkansas City, Ark	R.	438.3	165.94	2.8	1.66	.593	49.50	Mar. 27	United States gauge	William Starling makes this 165.33.
U. S. P. B. M. 84, Miss	L.	439.0	165.3	0.7	0.64	.914			Third district engineer *	
U. S. P. B. M. 85, Miss	L.	443.0	163.5	4.0	1.80	.450			do*	
Offutts, Miss	L.	444.6	163.0	1.6	0.50	.312			William Starling	Third district engineer's profile scales 161.1.
Gaines Landing, Ark	R.	449.5	161.9	4.9	1.10	.224			Third district engineer	
U. S. P. B. M. 87, Miss	L.	459.5?	158.8	10.0	3.10	.310			William Starling	Third district engineer's profile scales 158.1.
Linwood, Ark	R.	464.4	157.17	4.9	1.63	.333			Third district engineer	Profile scales 156.9.
Luna, Ark	R.	467.4	156.28	3.0	0.89	.297			do	
U. S. P. B. M. 88, Miss	L.	477.0?	153.3	9.6	2.98	.309			William Starling	
Greenville, Miss	L.	478.5	151.45	1.5	1.85	1.233	43.45	Mar. 17	United States gauge	William Starling makes this 151.73.
Vaucluse, Ark	R.	486.9	149.53	8.4	1.92	.229			Third district engineer	
Sunnyside, Ark	R.	490.0	148.31	3.1	1.22	.393			do	Profile scales 147.9.

..re, Miss	L.	491.1	147.7						Third district engineer*	
Do.	L.	491.1	148.2	1.1	0.11	.100			William Starling	
Lakeport, Ark	R.	495.4	146.7	4.3	1.50	.340			Third district engineer*	Table received in 1891 gives 147.18.
Longwood Landing, Miss	L.	501.8	144.9	5.9	1.80	.305			William Starling	
Lake Washington Landing, Miss.	L.	504.7	142.95	3.4	1.95	.574			do	
Grand Lake, Ark	R.	510.0	142.15	5.8	0.80	.151			Third district engineer	
Leota, Miss	L.	511.7	140.8						William Starling	Third district engineer's profile scales 141.2.
Hilliards, Ark	R.	512.5	141.44	2.5	0.71	.284			Third district engineer	
Sterling, Ark. (mean of two values).	R.	515.1	139.79	2.6	1.65	.635			Third district engineer	The difference in the values is 0.22 feet.
Carolina Landing, Miss	L.	516.8	138.8	1.7	0.99	.582			William Starling	
Louisiana State line	R.	518.0†	138.68						Third district engineer	
Ashton, Ark	R.	520.5	138.4	3.7	0.4	.108			do*	
Pilcher Point, La	R.	523.8	138.1	3.3	0.3	.091			do*	
Skipwith, Miss	L.	530.0	135.1	6.2	3.0	.484			do*	
Wilson Point, La	R.	531.4	134.6	1.4	0.5	.357			do*	
Mayersville, Miss	L.	533.0	133.9	1.6	0.7	.438			William Starling	
Cottonwood Landing, La	R.	534.5	132.6	1.5	1.3	.867			Third district engineer*	
Oakley Store, Miss	L.	537.6	132.48	3.1	0.17	.055			William Starling	
Ben Lomond Landing, Miss	L.	541.8	130.63	4.2	1.80	.429			do	
Lake Providence, La	R.	542.3	130.67	0.5	−0.04	−.080	41.05	Mar. 15	United States gauge	
Wyly, La	R.	545.0	130.4	2.7	0.27	.100			Third district engineer*	
Fitler, Miss	L.	552.0	128.23	7.0	2.17	3.10			William Starling	
Hays, Miss	L.	553.2	127.3	1.2	0.93	.775			do	
Transylvania, La	R.	558.0	126.7	4.8	0.6	.125			Third district engineer*	
Wilton, La	R.	560.0	125.5	2.0	1.2	.600			do*	
Pecan Grove, La	R.	566.2	122.9	6.2	2.6	.419			do*	
Duvalls, Miss	L.	568.3	123.28	2.1	−0.38	−0.181			William Starling	
Brunswick Landing, Miss	L.	573.0	120.88	4.7	2.40	.511			Third district engineer	William Starling makes this 121.42.
Henderson, La	R.	573.5	120.9						do*	
Omega, La	R.	578.1	119.9	5.1	0.98	.192			do*	
Purvis Grange, Miss	L.	583.0	118.79	4.9	1.11	.227			do*	
Halpin Landing, Miss., Butler's store.	L.	585.8	118.03	2.8	0.76	.271			do	
Browns Point, Miss	L.	590.0	116.71	4.2	1.32	.314			do	
Mouth Yazoo River, Allen place.	L.	595.0	115.98	5.0	0.73	.146			do	
Vicksburg, Miss	L.	599.3	115.09	4.3	0.89	.207	49.05	Apr. 24 to 25	United States gauge	
Kemp, Miss., on Kemp's residence.	L.	601.8	114.56	2.5	0.53	.212			Third district engineer	
Warrenton, Miss., on brick store.	L.	606.7	113.07	4.9	1.49	.304			do	
St. Joseph, La	R.	648.3	97.89	41.6	15.18	.365	45.15	Apr. 23	United States gauge	
Natchez, Miss	L.	700.3	85.49	52.0	12.4	.238	48.60	Apr. 23	do	
Fort Adams, Miss	L.	755.1	74.47	54.8	11.02	.201		Apr. 23	D. Babers	
Red River Landing, La	R.	765.3	72.52	10.2	1.95	.191	48.67	Apr. 23	United States gauge	
New Texas, La	R.	785.8	66.79	20.5	5.73	.280			Fourth district engineer	
Bayou Sara, La	L.	799.5	65.15	13.7	1.64	.120	41.20	Apr. 21	United States gauge	

* Elevation scaled from profile furnished by third district engineer.

High-water marks of 1890, Mississippi River, Cairo, Ill., to Carrollton, La.—Continued.

Station.	Bank.	Distance from Cairo.	Elevation above Cairo datum plane.	Distance between high-water marks.	Fall between high-water marks.	Slope per mile.	U. S. gauge reading.	Date of high water.	Authority for high water.	Remarks.
		Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*			
Waterloo, La	R.	805.2	63.58	5.7	1.57	.275	....	....	Fourth district engineer	
Hermitage, La	R.	807.8	63.42	2.6	0.16	.062	....	....	do	
Baton Rouge, La	L.	833.3	56.66	25.5	6.76	.265	36.60	Apr. 21 to 22	United States gauge	
Plaquemine, La	R.	853.5	52.96	20.2	3.70	.183	31.90	Apr. 22	do	
College Point, La	L.	903.0	45.14	49.5	7.82	.158	23.90	Mar. 16	do	
Carrollton, La	L.	957.0	37.01	54.0	8.13	.151	16.10	Mar. 13, 17	do	

NOTE.—The four negative slopes which appear in this table result from slight differences in determination of level by different authorities, affecting short distances on the river.

APPENDIX C 8.

High-water marks of 1891, Mississippi River, Cairo, Ill., to Carrollton, La.

Station.	Bank.	Distance from Cairo.	Elevation above Cairo datum plane.	Distance between high-water marks.	Fall between high-water marks.	Slope per mile.	U. S. gauge reading.	Date of high water.	Authority for high water.	Remarks.
		Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*			
Cairo, Ill	L.	0.0	337.05				46.21	Mar. 4 to 6	United States gauge	
Belmont, Mo	R.	21.3	328.44	21.3	8.61	.404	41.30	Mar. 6 to 7	...do	
New Madrid (Morrisson Landing), Mo.	R.	69.0	312.20	47.7	16.24	.340	36.40	Mar. 7 to 8	...do	
Gayoso, Mo	R.	105.7	294.61	36.7	17.59	.479		Mar. 8	G. W. Carleton, J. M. Delushmut, H. C. Schult.	H. C. Schult makes date March 9.
Caruthersville, Mo	R.	110.0	291.87	4.3	2.74	.637		Mar. 14	T. L. Ferguson, W. A. Joplin.	C. G. Shepherd makes date March 9.
Mitchell Point, Tenn	L.	122.3?	285.93					Mar. 9	H. D. Thompson	Location not well defined.
Cottonwood Point, Mo	R.	123.3	286.52	13.3	5.35	.402	35.90	Mar. 8	United States gauge	
Hickman Landing, Ark	R.	131.3	285.07?	8.0	1.45	.181		Mar. 7	G. W. Buckner	Compared with adjacent stations this seems too high.
Island 26		148.2?	275.60					Mar. 13	W. R. Warren	
Ward Landing, Ark	R.	148.2	275.50	16.9	9.57	.566		Mar. 13	W. W. Ward	
Fulton, Tenn	L.	175.4	262.45	27.2	13.05	.480	33.90	Mar. 13 to 14	United States gauge	
Memphis, Tenn	L.	230.0	238.87	54.6	23.58	.432	34.90	Mar. 10	...do	
Mhoon Landing, Miss	L.	275.9	218.08?				36.60?	Mar. 10 to 13	...do	Temporary gauge and reading probably too high, but amount of error not yet determined.
Austin, Miss	L.	288.0	212.85	58.0	26.02	.449		Mar. 24 to 28	T. G. Dabney, H. J. Irvine, observer.	
Helena, Ark	R.	306.5	206.68	18.5	6.17	.334	44.70	Mar. 27 to 28	United States gauge	
Friar Point, Miss	L.	319.0	201.88	12.5	4.80	.384		Mar. 26 to 27	T. G. Dabney; J. D. Robinson, observer.	201.36 on authority of E. Williams.
Sunflower Landing, Miss	L.	352.7	187.98	33.7	13.90	.412	40.90	Mar. 28 to Apr. 1.	United States gauge	188.15 on authority of T. G. Dabney.
Pushmataha, Miss	L.	359.3	186.23	6.6	1.75	.265		Mar. 29 to 30	T. G. Dabney; A. B. Nicholson, observer	
Coahoma and Bolivar County Line.	L.	365.0	184.13	5.7	2.10	.368			Mississippi levee board	
At P. B. M. 63, about 1 mile above Australia.	L.	369.0	183.42	4.0	0.71	.178			...do	
Australia, Miss	L.	370.0?	183.96					Mar. 27	D. J. Allen	Location doubtful.
About ¼ mile above Carsons	L.	377.0	180.63	8.0	2.79	.349			Mississippi levee board	
At B. M. 44/Y	L.	378.0	180.08	1.0	0.55	.550			...do	
About 1,000 feet above residence of late Jas. F. Stokes.	L.	379.0	179.24	1.0	0.84	.840			...do	
About ¼ mile below Waxhaw Landing, Miss.	L.	393.0	176.70						...do	

High-water marks of 1891, Mississippi River, Cairo, Ill., to Carrollton, La.—Continued.

Station.	Bank.	Distance from Cairo.	Elevation above Cairo datum plane.	Distance between high-water marks.	Fall between high-water marks.	Slope per mile.	U. S. gauge reading.	Date of high water.	Authority for high water.	Remarks.
		Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*			
Mouth of White River, Ark	R.	393.2	176.45	14.2	2.79	.196	47.72	Apr. 5	United States gauge	
Head of Island 73, Ark	R.	396.5	176.23	3.3	0.22	.667			Third district engineer	
Opposite Seller's residence, north part Rosedale, Miss.	L.	398.0	175.16	1.5	1.07	.713			Mississippi levee board	
Opposite Riverton Landing, Miss.	L.	399.0	174.96	1.0	0.20	.200			do	
Mouth of Knowlton Bayou	R.	400.0	174.63	1.0	0.33	.330			Third district engineer	
Mouth Arkansas River, Ark	R.	401.6	173.63	1.6	1.00	.625			do	
Amos Bayou, Ark	R.	402.5?	171.88						do	
Clark's Landing, on Lake Beulah.	L.	403.0	173.26	1.4	0.37	.264			Mississippi levee board	
Boggy Bayou, Ark	R.	403.5?	172.19						Third district engineer	
Ozark Bend, Ark	R.	408.0	172.63	5.0	0.63	.126			do	
Opossum Fork, Ark	R.	410.0	169.76						do	
Caulks Point, Ark	R.	413.3	170.83	5.3	1.80	.340			do	
P. B. M. 76 (Niblett Landing), Miss.	L.	415.0	170.74	1.7	0.09	.053			Mississippi levee board	
Stormville Landing, Miss	L.	416.0	170.72	1.0	0.02	.020			do	
P. B. M. 79, above Buck Ridge Landing.	L.	418.0	169.99	2.0	0.73	.365			do	
Good Luck Landing, Ark	R.	423.3	169.13	5.3	0.86	.162			Third district engineer	
Lucca Landing, Ark	R.	427.2	168.65	3.9	0.48	.123			do	
Chicot, Ark	R.	431.6	166.75	4.4	1.90	.432			do	
About ½ mile below Eutaw Landing.	L.	433.0	166.06	1.4	0.69	.493			Mississippi levee board	
About ½ mile above Mound Landing.	L.	435.5	165.89	2.5	0.17	.068			do	
Arkansas City, Ark	R.	438.3	164.84	2.8	1.05	.375	48.4	Apr. 3 to 7.	United States gauge	
In Timberlake Wood, north end Government work.	L.	440.5	162.49						Mississippi levee board	
At P. B. M. 86	L.	445.0	162.23	6.7	2.61	.390			do	
Gaines Landing, Ark	L.	449.5	161.11	4.5	1.12	.249			Third district engineer	
		457.0	159.03	7.5	2.08	.277			Mississippi levee board	Location not described.
About 1,800 feet above P. B. M. 87.	L.	459.0	158.35	2.0	0.68	.340			do	
Near U. S. P. B. M. 87	L.	459.5	158.07	0.5	0.28	.560			do	
Linwood Landing, Ark	R.	464.4	156.47	4.9	1.60	.327			Third district engineer	
Luna Landing, Ark	R.	467.4	156.03	3.0	0.44	.147			do	
At bend or angle of levee	L.	475.0	153.25	7.6	2.78	.366			Mississippi levee board	
Greenville, Miss	L.	478.5	151.25	3.5	2.00	.571	43.25	Apr. 2 to 3.	United States gauge	

[illegible] on H. D. Halsey place.	L.	481.5	150.14	3.0	1.11	.370			Mississippi levee board	
2,200 feet below Warfield's store.	L.	484.0	149.18	2.5	0.96	.384			do	
Vaucluse, Ark	R.	486.9	149.42	2.9	—0.24	—.083			Third district engineer	
Sunnyside, Ark	R.	490.0	147.81	3.1	1.61	.519			do	
Refuge, Miss.	L.	491.1	147.41	1.1	0.40	.364		Apr. 4	William Paul	
Lakeport, Ark	R.	495.4	146.57?					Apr. 4	W. W. Ford	
			146.87	4.3	0.54	.128			Third district engineer	
About 600 feet above Glenora Gin, Miss.	L.	499.0	145.21	3.6	1.66	.461			Mississippi levee board	
Below Longwood Landing	L.	503.0	143.38	4.0	1.83	.458			do	
Above Leota (above old levee).	L.	505.0	142.45	2.0	0.93	.465			do	Below old levee; el. 141.95.
Grand Lake, Ark	R.	510.0	141.31	5.0	1.14	.228			Third district engineer	
Leota, Miss	L.	511.5	140.43	1.5	0.88	.587			Mississippi Levee Board	
Hilliards Landings, Ark	R.	512.5	140.91	1.0	—0.48	—.480			Third district engineer	
Sterling, Ark	R.	515.1	139.68	2.6	1.23	.473			Third district engineer	
Carolina Landing, Miss	L.	516.8	139.4	1.7	0.28	.165			Mississippi Levee Board	
Louisiana-Arkansas State Line.	R.	520.5?	138.44						Third district engineer	Location doubtful.
Lower Ashton, La	R.	520.5	138.34	3.70	1.06	.286			Third district engineer	
Pilchers Point, La	R.	523.8	137.21	3.3	1.13	.342			Third district engineer	
Below Carolina Landing	L.	526.5	136.91	2.7	0.30	.111			Mississippi Levee Board	
Near Opossum Point, La. (old river).	R.	527.5	136.81						Third district engineer	
Above Skipwith, Miss	L.	528	135.25	1.5	1.66	1.107			Mississippi Levee Board	
Below Skipwith, Miss	L.	531.1	134.84	3.0	0.41	.137			Mississippi Levee Board	
One mile above Mayersville, Miss.	L.	532	133.66	1.0	1.18	1.180			Mississippi Levee Board	
Cottonwood Plantation, La	R.	534.0	132.92	2.0	0.74	.370			Third district engineer	
Donna Vista, La	R.	536.0	132.62	2.0	0.30	.150			Third district engineer	
Longwood Landing, La	R.	537.5	132.04	1.5	0.58	.387			Third district engineer	
Upper Elton, La	R.	539.0	131.67	1.5	0.37	.247			Third district engineer	
Middle Elton, La	R.	540.0	131.50	1.0	0.17	.170			Third district engineer	
Lower Elton, La	R.	541.5	130.8	1.5	0.70	.467			Third district engineer	
Lake Providence, La	R.	542.8	130.62	0.8	0.18	.225	41.00	Apr. 1 to 4	United States gauge	
Hagaman, La	R.	543.0	130.54	0.7	0.08	.114			Third district engineer	
Blue Ridge, La	R.	547.0	129.94	4.0	0.60	.150			Third district engineer	
Otter Bayou, La	R.	549.0	129.50	2.0	0.44	.220			Third district engineer	
Near B. M. ½ about opp. Tallulah Landing.	L.	552	128.13	3.0	1.37	.457			Mississippi Levee Board	
Benjamin, La	R.	553.0?	126.31						Third District Engineer	
½-mile below Tallulah	L.	553.1?	128.14						Mississippi Levee Board	
Below Hays Landing, Miss	L.	555	126.05	3.0	2.08	.693			Mississippi Levee Board	
Transylvania, La	R.	558.0	126.20	3.0	—0.15	—.050			Third district engineer	E. W. Constant reported .42 feet higher than this.
At Arcadia Landing, Miss	L.	560	124.59						Mississippi Levee Board	
Mean		560.1	125.37	2.1	0.83	.395				
Wilton Landing (lower), La	R.	560.2	126.15						Third district engineer	
Goodrich Landing, La	R.	562	125.23	1.9	0.14	.737			do	
Salem, La	R.	564	124.33	2.0	0.90	.450			do	

High-water marks of 1891, Mississippi River, Cairo, Ill., to Carrollton, La.—Continued.

Station.	Bank.	Distance from Cairo.	Elevation above Cairo datum plane.	Distance between high-water marks.	Fall between high-water marks.	Slope per mile.	U. S. gauge reading.	Date of high water.	Authority for high water.	Remarks.
		Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*	*Feet.*			
Below Arcadia Landing, Miss.	L.	565.5	123.32	1.5	1.01	.673			Mississippi Levee Board	
At Duvalls Landing, Miss	L.	568	123.18	2.5	0.14	.056			do	
Lower end Pecan Grove Levee. (Upper side of levee, in pocket.)	R.	571	123.57						Third district engineer	Approximatly 2 feet above water or lower side of old levee.
Above Brunswick Landing, Miss.	L.	572.0	121.63	4.0	1.55	.388			Mississippi Levee Board	
At Brunswick Landing, Miss.	L.	573.0	120.80	1.0	0.83	.830			do	Levee engineer makes this 121.25.
Henderson Landing	R.	573.5	120.88						Third district engineer	119.61, authority of J. B. Galloway.
Omega, La	R.	578.1	119.34	5.1	1.46	.286			do	
Morancys, La	R.	580.0	118.62	1.9	0.72	.379			do	
Purvis Grange, Miss	L.	583	118.46	3.0	0.16	.053			Arthur Hider	
Cabin Teele, La	R.	584.3	117.27	1.3	1.19	.915			Third district engineer	
Halpino Landing, Miss. Butler's store.	L.	585.7	117.53	1.4	—0.26	—.186			Arthur Hider	
Duckport, La	R.	589.7	116.05	4.0	1.48	.370			Third district engineer	
Youngs Point, La	R.	593.4	115.78	3.7	0.27	.073			do	
Mouth of Yazoo River; Allen Place; Sledge residence.	L.	595	114.98	1.6	0.80	.500			Arthur Hider	
Vicksburg, Miss	L.	599.3	114.14	4.3	0.84	.195			United States gauge	
Kemp's, Miss.; on Kemp's residence.	L.	601.8	113.56	2.5	0.58	.232			Arthur Hider	
Warrenton, Miss.; on brick store.		606.7	112.42	4.9	1.14	.236			do	
St. Joseph, La	R.	648.3	96.54	41.6	15.88	.382	43.8	Apr. 11	United States gauge	
Natchez, Miss	L.	700.3	83.39	52.0	13.15	.253	46.50	Apr. 11 to 12	do	
Fort Adams, Miss	L.	755.1	71.30	54.8	12.09	.221		Apr. 14	C. M. Stricker	D. Babers reports 3 inches lower than this.
Red River Landing, La	R.	765.3	69.33	10.2	1.97	.193	45.48	Apr. 26 to May 4	United States gauge	
Bayou Sara, La	L.	799.5	62.75	34.2	6.58	.192	38.80	Apr. 29 to May 6	do	
Waterloo, La	R.	805.2	61.50	5.7	1.25	.219		May 3	C. Pimciaux	
Baton Rouge, La	L.	833.3	55.61	28.1	5.89	.210	35.55	May 3, 5	United States gauge	
Plaquemine, La	R.	853.5	52.11	20.2	3.50	.173	31.05	Apr. 15 to 22	do	
Donaldsonville, La	R.	885.4	47.04	31.9	5.07	.159	27.90	Mar. 18, 20	do	
College Point, La	L.	903.0	44.29	17.6	2.75	.156	23.05	Mar. 31	do	
Carrollton, La	L.	957.0	36.91	54.0	7.38	.137	16.00	Mar. 16	do	

NOTE.—The four negative slopes which appear in this table result from slight differences in determination of level by different authorities affecting short distances on the river.

APPENDIX C 9.

MISSISSIPPI RIVER AND PRINCIPAL TRIBUTARIES, EXCEPT THE MISSOURI—HIGH AND LOW WATERS REFERRED TO PRESENT OR MOST RECENT GAUGES.

NOTE A.—The † before a quantity indicates that the gauge record is incomplete, and that it is possible the period of extreme high or low water is not included.

NOTE B.—At certain stations early records exist which are not used in this table because elevation of their gauge zeros has not been established with certainty.

MISSISSIPPI RIVER, HASTINGS, MINNESOTA.

[Zero of gauge approximately 691.30 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		Feet.	
1879	July 12-13	†10.70	Nov. 24	0.70	U. S. Engineer gauge records.
1880	June 17	16.80	Oct. 11, 14-15	1.70	Do.
1881	Apr. 30	18.00	Aug. 15-18	3.50	Do.
1882	Apr. 12-13	13.70	Dec. 12-15	2.40	Do.
1883	Apr. 24-26	13.10	Nov. 16-18	1.00	Do.
1884	May 6	11.20	Aug. 16	1.70	Do.
1885	Apr. 28-30	9.20	Dec. 5	1.00	Do.
1886	Apr. 20-21	10.00	Nov. 20	0.30	Do.
1887	Apr. 18-19	11.00	Nov. 28-30	0.10	Do.
1888	May 11	14.30	Dec. 13-14	0.30	Do.
1889	May 21-23	4.20	Nov. 28-30	—0.40	Do.
1890	June 12-24	6.6	Dec. 1	—0.4	Do.

MISSISSIPPI RIVER, WINONA, MINNESOTA.

[Zero of gauge approximately 660.00 feet above the Cairo datum plane.]

Year.	Highest day.	Gauge reading.	Lowest day.	Gauge reading.	Authority.
1878			Sept. 19	†0.08	U. S. Engineer gauge records.
1879	July 17-18	9.00	March 27	†0.71	Do.
1880	June 18	16.87	Oct. 14	1.54	Do.
1881	Oct. 5	14.33	Apr. 7	2.70	High water, U. S. engineer gauge records. Low water, Mississippi River Commission discharge party gauge records.
1882	Apr. 13-14	11.83	Dec. 6	2.42	U. S. Engineer gauge records.
1883	Apr. 21	12.17	Nov. 30, Dec. 1	1.00	Do.
1884	Sept. 16	11.33	Jan. 2	1.04	Do.
1885	May 1-2	8.83	Dec. 5-6	1.92	Do.
1886	Apr. 23	10.63	Nov. 29	—0.29	Do.
1887	Apr. 20	10.92	Nov. 28-30	0.75	Do.
1888	May 4, 8	14.92	Dec. 22	1.33	Do.
1889	May 25	5.25	Dec. 30	1.33	Do.
1890	June 12-14	8.2	Jan. 1	—0.2	Do.

MISSISSIPPI RIVER, PRAIRIE DU CHIEN, WISCONSIN.

[Zero of gauge approximately 624.59 feet above the Cairo datum plane.]

Year.	Highest day.	Gauge reading.	Lowest day.	Gauge reading.	Authority.
1878			Dec. 12	†1.00	U. S. Engineer gauge records.
1879	May 26	40.40	Sept. 26-30	1.80	Do.
1880	July 1-2	†14.10	Nov. 29-30	2.00	Do.
1881	Oct. 21	19.50	Aug. 23-25	3.70	Do.
1882	Apr. 19	15.10	Oct. 1, 5, 7; Dec. 9-11	3.50	Do.
1883	Apr. 26	15.80	Nov. 18-20	1.30	Do.
1884	Sept. 22	13.70	Aug. 16-20; Nov. 29	3.00	Do.
1885	May 5-6	11.75	Dec. 6	1.45	Do.
1886	Apr. 27	14.45	Nov. 28	1.15	Do.
1887	Apr. 23	14.25	Nov. 21	1.55	Do.
1888	May 13	20.60	Dec. 16	1.45	Do.
1889	May 28-29	7.00	Dec. 30	0.40	Do.
1890	June 27	12.00	Jan. 1	1.3	Do.

MISSISSIPPI RIVER, HANNIBAL, MISSOURI.

[Zero of gauge 469.72 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1879....	June 3-4..........	10.62	Dec. 23............	0.87	Major Mackenzie (from bridge gauge records).
1880....	July 3............	18.67	Nov. 25...........	1.06	High water, Major Mackenzie; low water, Mississippi River Commission discharge party.
1881....	Oct. 27...........	20.58	Feb. 1, 6..........	3.58	Major Mackenzie (from bridge gauge records).
1882....	July 2............	18.42	Dec. 12............	1.58	Do.
1883....	May 20............	17.58	Dec. 22............	0.33	Do.
1884....	Apr. 3............	18.50	Mar. 13...........	2.17	Do.
1885....	Mar. 16...........	13.25	Dec. 10-11.........	0.75	Do.
1886....	May 9.............	17.08	Dec. 2-5...........	-0.67	Do.
1887....	Feb. 13...........	12.00	Dec. 2-3, 22-24.....	0.50	Do.
1888....	May 17............	21.58	Dec. 23-24.........	0.50	Do.
1889....	May 30............	8.67	Dec. 6.............	-0.25	Do.
1890....	July 3............	13.50	Jan. 9.............	-1.75	Do.

MISSISSIPPI RIVER, GRAFTON, ILLINOIS.

[Zero of gauge 232.72 feet above the Cairo datum plane.]

1879....	....	....	Dec. 24............	192.51	U. S. Engineer gauge records.
1880....	July 8-9..........	210.41	Nov. 27...........	193.20	Do.
1881....	May 5.............	214.25	Jan. 30............	194.48	Do.
1882....	July 5-6..........	214.50	Dec. 14-15.........	193.65	Do.
1883....	June 25...........	214.70	Dec. 27............	193.80	Do.
1884....	Apr. 6-7..........	212.45	Dec. 22............	194.70	Do.
1885....	Apr. 29...........	208.64	Dec. 16............	193.20	Do.
1886....	May 15............	209.83	Dec. 4.............	191.30	Do.
1887....	Feb. 16...........	205.01	Dec. 28-29.........	191.30	Do.
1888....	May 30............	213.76	Dec. 24............	192.30	Do.
1889....	May 31............	205.75	Oct. 14...........	192.25	Do.
1890....	July 2............	205.75	Dec. 17............	191.77	Do.

MISSISSIPPI RIVER, ST. LOUIS, MISSOURI.

[Zero of gauge 400.23 feet above the Cairo datum plane.]

1785....	Apr...............	42.0	....	....	U. S. Signal Service, on the authority of Dr. Engleman.
1826....	....	33.81	....	....	Major Merrill (Chief of Engineers' Report, 1872, page 429.)
1828....	....	36.4	....	....	Humphreys and Abbot Report, page 171 (U. S. Signal Service, on the authority of Dr. Engleman, makes this 33.6.)
1838....	May 28............	27.0	....	....	U. S. Signal service, on the authority of Dr. Engleman.
1843....	May 2.............	27.2	....	....	Do.
1844....	June 28...........	41.39	....	....	Major Merrill (Chief of Engineers' Report, 1872, page 429.)
1845....	June 27...........	32.4	....	....	U. S. Signal Service, on the authority of Dr. Engleman.
1846....	May 10............	25.0	....	....	Do.
1849....	Mar. 10...........	27.4	....	....	Do.
1851....	June 10...........	36.61	....	....	Humphreys and Abbot Report, page 171, (U. S. Signal Service, on the authority of Dr. Engleman, makes this 27.0.)
1852....	May 20............	28.0	....	....	Do.
1853....	May 7.............	30.0	....	....	Do.
1855....	....	37.1	....	....	Major Merrill (Chief of Engineers' Report, 1872, page 429.)
1856....	May 9.............	27.4	....	....	U. S. Signal Service, on the authority of Dr. Engleman.
1858....	June 15...........	37.21	....	....	Humphreys and Abbot Report, page 171.)

MISSISSIPPI RIVER, ST. LOUIS, MISSOURI—Continued.

[Zero of gauge 400.23 above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		Feet.	
1860			Dec. 27	.6	St. Louis city gauge records, by adding 33.8 feet, on the authority of Major Merrill (Chief of Engineers' Report, 1872, page 429.)
1861	May 15	25.47	Jan. 1	1.33	Do.
1862	Apr. 26	31.45	Jan. 8	3.48	Do.
1863	Mar. 4, 9	18.02	Dec. 21	0.00	Do.
1864	May 14	20.33	Jan. 2	1.22	Do.
1865	July 28	26.81	Feb. 1–2	1.19	Do.
1866	Apr. 25	26.77	Dec. 21	5.79	Do.
1867	May 1	28.21	Dec. 19	1.27	Do.
1868	May 14–15	24.19	Jan. 14	0.85	Do.
1869	July 24	29.31	Jan. 2	5.61	Do.
1870	Apr. 16	26.21	Dec. 24	5.26	Do.
1871	Mar. 17	21.82	Dec. 21	2.84	Do.
1872	June 12–14	23.00	Dec. 4	2.50	Do.
1873	Apr. 11	25.45	Nov. 30–Dec. 2	4.67	Do.
1874	June 19–20	18.40	Dec. 31	2.80	U. S. Engineer gauge records.
1875	Aug. 3	29.80	Jan. 3	2.30	Do.
1876	May 10	32.00	Feb. 7	5.00	Do.
1877	June 14	26.60	Oct. 4	6.85	Do.
1878	June 15	25.75	Dec. 25	5.65	Do.
1879	July 3	21.15	Dec. 26	3.50	Do.
1880	July 12	25.50	Nov. 29	2.80	Do.
1881	May 6	33.65	Feb. 5–6	7.55	Do.
1882	July 5	32.39	Dec. 18	2.85	Do.
1883	June 26	34.80	Jan. 12	4.45	Do.
1884	Apr. 9–10	28.10	Jan. 5	3.15	Do.
1885	June 17	27.10	Dec. 15	2.10	Do.
1886	May 13	27.00	Dec. 5	1.45	Do.
1887	Apr. 3	20.70	Dec. 27	1.02	Do.
1888	June 4	29.35	Dec. 25	3.25	Do.
1889	June 1	24.65	Feb. 26	2.50	Do.
1890	July 1	20.60	Dec. 17	2.95	Do.
1891	Apr. 25	23.40			Do.

MISSISSIPPI RIVER, GRAND TOWER, ILLINOIS.

[Zero of gauge 344.65 feet above the Cairo datum plane.]

1885	June 24	23.3	Dec. 18–20	2.5	U. S. Signal Service gauge records.
1886	May 15	23.5	Dec. 8	— 0.1	Do.
1887	Mar. 20	17.20	Dec. 31	0.20	Do.
1888	June 4–5	24.50	Jan. 1	0.00	Do.
1889	June 2	20.50	Oct. 18–22	2.10	Do.
1890	Jan. 16, Apr. 30	17.00	Dec. 19–21	1.90	Do.

MISSISSIPPI RIVER, GRAY'S POINT, MISSOURI.

[Zero of gauge 321.28 feet above the Cairo datum plane.]

1879	July 5	23.90	Dec. 26	6.00	Rob Berry, gaugekeeper.
1880	July 10	25.86	Dec. 31	0.91	U. S. Engineer gauge records.
1881	May 8	32.96	Jan. 1	1.46	Do.
1882	Feb. 24	32.16	Dec. 19	3.16	Do.
1883	June 27–28	34.31	Jan. 23–24	3.41	High-water, U. S. Engineer gauge records. Low-water, Mississippi River Commission gauge records.
1884	Apr. 10–11	28.15	Dec. 27	3.60	Mississippi River Commission gauge records.
1885	June 24	27.35	Dec. 19	5.58	Do.
1886	May 15	27.45	Dec. 8	3.60	Do.
1887	Mar. 10	22.65	Dec. 31	1.32	Do.
1888	June 4–5	28.56	Jan. 1	1.00	U. S. Engineer gauge records.
1889	June 2	25.80	Oct. 19–24	5.25	Do.
1890	Apr. 6	25.35	Dec. 19–20	4.90	Do.
1891	Apr. 26	23.10			Mississippi River Commission gauge records.

For Cairo see Ohio River.

MISSISSIPPI RIVER, BELMONT, MISSOURI.*

[Zero of gauge 287.14 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1880		39.17			High-water mark at Columbus, Ky.
1882	Feb. 26	44.80			Mississippi River Commission gauge records of Columbus.
1883	Feb. 26	45.28	Sept. 30	4.60	High-water mark at Columbus, Ky.; low-water, Mississippi River Commission gauge records.
1884	Feb. 22-24	45.80?	Dec. 10	6.80?	Mississippi River Commission gauge records.
1885	Jan. 26	36.10	Oct. 20	7.91	Do.
1886	Apr. 19	44.58	Nov. 11-13	4.40	Do.
1887	Mar. 10-11	43.00	Dec. 31	1.42	Do.
1888	Apr. 6	41.05	Jan. 1	1.38	Do.
1889	June 24	31.41	Oct. 23	2.85	Do.
1890	Apr. 6	43.03	Dec. 24-25	8.70	Do.
1891	Mar. 6-7	41.30			Do.

* See note B, page 3555.

MISSISSIPPI RIVER, NEW MADRID [MORRISSON LANDING], MISSOURI.

[Zero of gauge 275.80 feet above the Cairo datum plane.]

1880	Mar. 24-25	34.70	Nov. 29-30	2.20	Mississippi River Commission gauge records.
1882			Dec. 19-20	3.70	Do.
1883			Oct. 1	1.72	Do.
1884	Feb. 23-25	41.50	Dec. 10	3.90	Do.
1885	Jan. 26	31.45	Oct. 20-21	5.25	Do.
1886	Apr. 20	40.40	Nov. 13	1.92	Do.
1887	Mar. 11-12	37.78	Dec. 31	0.30	Do.
1888	Apr. 6	36.00	Jan. 2	0.10	Do.
1889	June 24-25	27.50	Oct. 23-25	1.80	Do.
1890	Mar. 15	38.15	Dec. 26	7.50	Do.
1891	Mar. 7-8	36.40			Do.

MISSISSIPPI RIVER, COTTONWOOD POINT, MISSOURI.

[Zero of gauge 250.62 feet above the Cairo datum plane.]

1880	Mar. 23-26	35.50	Nov. 30, Dec. 1	2.10	Mississippi River Commission gauge records.
1881	Apr. 23-25	35.20	Jan. 8-9	1.60	Do.
1882	Feb. 28	37.53	Dec. 19-20	3.60	Do.
1883	Feb. 28	37.85	Oct. 1-2	1.00	Do.
1884	Feb. 23-27	37.45	Dec. 10-11	2.70	Do.
1885	Jan. 26-27	31.90			Do.
1886	Apr. 21	37.09			High-water correspondent.
1889	June 25	27.60	Oct. 24-25	.35	Mississippi River Commission gauge records.
1890	Mar. 15-16	36.40	Dec. 26	5.10	Do.
1891	Mar. 8	35.90			Do.

MISSISSIPPI RIVER, FULTON, TENNESSEE.

[Zero of gauge 228.55 feet above the Cairo datum plane.]

1879			Nov. 13-15	†2.10	Mississippi River Commission gauge records.
1880	Mar. 26	34.18	Nov. 1	4.65	Do.
1881	Apr. 26	34.29			Do.
1882	Mar. 1-2	36.69	Dec. 20	6.64	Do.
1883			Oct. 1-2	4.68	Do.
1884	Feb. 24	35.70	Dec. 11	5.48	Do.
1885	Jan. 28	29.92	Oct. 21-22	6.25	Do.
1886	Apr. 22	35.37	Nov. 14	3.86	Do.
1887	Mar. 12	34.61	Nov. 22	2.22	Do.
1888	Apr. 10	33.61	Jan. 3	1.60	Do.
1889	June 26	25.68	Oct. 23	2.30	Do.
1890	Mar. 22	34.90	Dec. 27-28	7.67	Do.
1891	Mar. 13-14	33.90			Do.

MISSISSIPPI RIVER, MEMPHIS, TENNESSEE.

[Zero of gauge, 203.97 feet above the Cairo datum plane.]

Year.	Highest. Day.	Highest. Gauge reading.	Lowest. Day.	Lowest. Gauge reading.	Authority.
		Feet.		*Feet.*	
1828		32.86			Humphreys and Abbot Report, page 171.
1844	July	33.16			Do.
1848			Oct. 29, Nov. 2, 3	1.36	Humphreys and Abbot Report, page 515; deducting 1.14. Captain Willard (Ms. 1891).
1849	Feb. 8, 16	30.86	Sept. 23	3.46	Humphreys and Abbot Report, page 516; deducting 1.14. Captain Willard (Ms. 1891).
1850	May 14–21	33.56	Nov. 3–4	2.46	Humphreys and Abbot Report, page 517; deducting 1.14. Captain Willard (Ms. 1891).
1851	Mar. 11	33.16	Dec. 27–31	3.46	Humphreys and Abbot Report, page 518; deducting 1.14. Captain Willard (Ms. 1891).
1852	Apr. 21–23	32.96			Humphreys and Abbot Report, page 522; deducting 1.14. Captain Willard (Ms. 1891).
1858	June 23	34.16	Oct. 24–27	2.86	Humphreys and Abbot Report, page 532; deducting 1.14. Captain Willard (Ms. 1891).
1859	May 12–13	34.06			Captain Willard (Ms. 1891.)
1862		34.78			Do.
1865		33.68			Do.
1867	Mar. 26	33.95?			Major Benyaurd (Chief of Engineers' Report, 1881, page 1444.)
1871			Dec. 29	—0.92	U. S. Engineer gauge records.
1872	Apr. 24	31.50	Dec. 25	—0.95	Do.
1873	Mar. 3	32.50	Oct. 30	1.00	Do.
1874	May 2	34.00	Nov. 16	1.40	Do.
1875	Aug. 15–17	33.05	Jan. 27	3.20	Do.
1876	Apr. 8–9	34.08	Dec. 30	1.20	Do.
1877	Apr. 29	32.05	Jan. 2	0.75	Do.
1878	May 2	29.10	Oct. 24, Nov. 3	2.90	Do.
1879	Jan. 29	28.10	Oct. 9–12, Nov. 11	1.05	Do.
1880	Mar. 24–29	33.40	Oct. 31	2.60	Do.
1881	Apr. 27–28	33.30	Sept. 11–12	2.10	Do.
1882	Mar. 6–9	35.15	Dec. 21	3.50	Do.
1883	Mar. 6–8	34.75	Oct. 2	1.90	Do.
1884	Mar. 1–3	34.15	Dec. 11–12	3.10	Do.
1885	Jan. 28	29.25	Oct. 21–13	4.15	Do.
1886	Apr. 28	34.80	Nov. 14–16	2.50	Do.
1887	Mar. 9–10	35.30	Nov. 20–24	1.20	Do.
1888	Apr. 11–12	34.20	Jan. 4	0.80	Do.
1889	June 26–27	26.60	Oct. 24–26	1.60	Do.
1890	Mar. 23–24, Apr. 4–5	35.60	Dec. 26–27	7.20	Do.
1891	Mar. 10	34.90			Do.

MISSISSIPPI RIVER, MHOON LANDING, MISSISSIPPI.

[Zero of gauge, 181.48 feet above the Cairo datum plane.]

1880		36.10			High-water mark, Mississippi River Commission levels.
1882	Mar. 8–9	39.80	Dec. 22	5.90	Mississippi River Commission gauge records.
1883	Mar. 7–8	40.20	Oct. 1–2	2.40	Do.
1884	Mar. 5–6	38.90?	Dec. 12	2.60	Do.
1885	Jan. 28–29	33.80			Do.
1889	June 27	27.70	Oct. 26–31	2.20	Do.
1890	Mar. 28–Apr. 2	38.50	Aug. 26–27	8.10	Do.
1891	Mar. 10–13	35.4?			Do.

MISSISSIPPI RIVER, HELENA, ARKANSAS.

[Zero of gauge, 161.98 feet above the Cairo datum plane.]

Year.	Highest. Day.	Highest. Gauge reading.	Lowest. Day.	Lowest. Gauge reading.	Authority.
		Feet.		*Feet.*	
1828		43.11			Humphreys and Abbot Report, page 171; corrected by deducting 0.39 feet. Captain Benyaurd (Chief of Engineers' Report, 1876, page 606).
1844		42.21			Do.
1849		42.81			Do.
1850	May 1	42.81			Do.
1851		39.81			Do.
1858	July 2-6	44.61			Humphreys and Abbot Report, page 533; corrected by deducting 0.39 feet. Captain Benyaurd (Chief of Engineers' Report, 1876, page 606).
1859	Mar. 22	43.61			Humphreys and Abbot Report, page 171; corrected by deducting 0.39 feet. Captain Benyaurd (Chief of Engineers' Report, 1876, page 606).
1862		46.40			Major Merrill (Chief of Engineers' Report, 1872, page 432); corrected by adding 2.20 feet. Captain Benyaurd (Chief of Engineers' Report, 1876, page 606).
1865		44.40			Major Abbot (Chief of Engineers' Report, 1869, page 336, and 1875, page 568).
1867		45.82			Major Merrill (Chief of Engineers' Report, 1872, page 432); corrected by adding 2.20 feet. Captain Benyaurd (Chief of Engineers' Report, 1876, page 606).
1871			Dec. 29	1.15	U. S. Engineer gauge records.
1872	Apr. 26	39.03	Dec. 26	0.00	Do.
1873	Mar. 6	40.00	Oct. 17, 19, 20, 22	4.00	Do.
1874	May 11	45.82	Nov. 16	3.70	Do.
1875	Apr. 12-14	42.40	Jan. 28	6.50	Do.
1876	Apr. 18-19	44.85	Dec. 31	3.00	Do.
1877	Apr. 30-May 1	41.80	Jan. 4	1.70	Do.
1878	May 3-4	38.75			Do.
1879	Jan. 31	37.25			Do.
1880	Mar. 31	43.70	Nov. 3	8.10	Do.
1881	May 14	43.74	Sept. 15	6.25	Do.
1882	Mar. 9	47.20	Dec. 22-23	8.60	Do.
1883	Mar. 8-9	46.90	Oct. 1-2	6.40	Do.
1884	Mar. 6	47.00	Dec. 13	7.25	Do.
1885	Jan. 30	40.70	Oct. 23	8.00	Do.
1886	Apr. 30	48.10	Nov. 16	3.00	Do.
1887	Mar. 21-22	46.40	Nov. 23	0.25	Do.
1888	Apr. 14-15	42.80	Jan. 5	-0.20	Do.
1889	June 28	34.10	Oct. 26	1.60	Do.
1890	Mar. 29-30	47.72	Aug. 27	10.02	Do.
1891	Mar. 27-28	44.70			Do.

MISSISSIPPI RIVER, GLENDALE, MISSISSIPPI.

[Zero of gauge, 168.07 feet above the Cairo datum plane.]

1880	Mar. 30-Apr. 3	37.10			Mississippi River Commission gauge records.
1881	May 13-15	37.90			Do.

MISSISSIPPI RIVER, ST. LOUIS LANDING, ARKANSAS.

[Zero of gauge, 141.33 feet above the Cairo datum plane.]

1884	Mar. 6-7	48.20	Dec. 14	14.35?	Mississippi River Commission gauge records.

MISSISSIPPI RIVER, SUNFLOWER LANDING, MISSISSIPPI.

[Zero of gauge, 147.08 feet above the Cairo datum plane.]

Year.	Highest. Day.	Highest. Gauge reading.	Lowest. Day.	Lowest. Gauge reading.	Authority.
		Feet.		Feet.	
1880		40.61			High-water mark, Mississippi River Commission levels.
1881		39.75			Do.
1882		41.65	Dec. 2	7.20	High-water mark, Mississippi River Commission levels. Low water, Mississippi River Commission gauge records.
1883	Mar. 10–11	41.75	Sept. 28	5.00	Mississippi River Commission gauge records.
1889	June 29	33.50			Do.
1890	Mar. 30–Apr. 1	42.90	Aug. 27	9.10	Do.
1891	Mar. 28–Apr. 1	40.90			Do.

MISSISSIPPI RIVER, MALONE LANDING, MISSISSIPPI.

[Zero of gauge, 154.96 feet above the Cairo datum plane.]

1880		31.04	Nov. 3	0.10	High-water mark, Mississippi River Commission levels. Low water, Mississippi River Commission gauge records.
1881	May 14–15	30.90	Sept. 19–20	−1.40	Mississippi River Commission gauge records.
1882	Feb. 28	32.65	Dec. 24	0.09	Do.

MISSISSIPPI RIVER, MOUTH OF WHITE RIVER, ARKANSAS.

[Zero of gauge, 128.73 feet above the Cairo datum plane.]

1862	Apr. 20	48.2			Major Abbot (Chief of Engineers' Report 1869, page 336); Major Benyaurd (Chief of Engineers' Report 1881, page 1445).
1867	Mar. 30	46.8			Major Merrill (Chief of Engineers' Report 1872, page 432, corrected by adding 3.2 feet); Captain Benyaurd (Chief of Engineers' Report 1876, page 611).
1871			Dec.	1.37	Do.
1872	Apr. 30–May 1	40.20	Dec. 28	0.0	U. S. Engineer gauge records.
1873	Apr. 25–26	42.90			Do.
1874	Apr. 28	46.60	Nov. 16	2.70	High water, Major Benyaurd (Ms. and Chief of Engineers' Report 1876, page 611); low water, U. S. Engineer gauge records.
1875	Apr. 16–17	45.00	Jan. 28	6.80	U. S. Engineer gauge records.
1876	Apr. 8–15	46.70	Dec. 26	2.90	Do.
1877	May 5–6	44.60	Jan. 8	2.20	Do.
1879			Oct. 14–15	2.40	Do.
1880	Mar. 23–25	46.55	Nov. 4	7.00	Do.
1881	May 15–18	45.70	Sept. 14	5.50	Do.
1882	Feb. 28	48.40	Dec. 23–24	9.70	Do.
1883	Mar. 9–12	48.00	Oct. 3	6.80	Do.
1884	Mar. 7–8	47.90	Dec. 13	9.00	Do.
1885	Jan. 23–25	43.60	Oct. 24	10.00	Do.
1886	May 4	48.20	Nov. 15–16	5.90	Do.
1887	Mar. 23–25	47.75	Nov. 23–24	3.50	Do.
1888	Apr. 20.	45.55	Jan. 5–6	4.50	Do.
1889	June 29.	37.70	Oct. 27–29	5.10	Do.
1890	Mar. 31	50.40	Aug. 14–16	13.20	Do.
1891	Apr. 5	47.72			Do.

MISSISSIPPI RIVER, ARKANSAS CITY, ARKANSAS.

[Zero of gauge, 116.44 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1880....	May 20–27	45.10	Nov. 4	5.90	Mississippi River Commission gauge records.
1881....	May 16–18	44.30	Jan. 14............	1.80	Do.
1882....	Feb. 28............	47.10	Dec. 23–24.........	7.50	Do.
1883....	Mar. 11	46.35	Oct. 3–4	4.20	Do.
1884....	Mar. 7–9	46.50	Sept. 29	7.30	Do.
1885....	May 7–9	42.60	Oct. 24–25	7.70	Do.
1886....	May 4–5	46.90	Nov. 16–18	3.00	Do.
1887....	Mar. 25–27	46.65	Nov. 24–25	0.30	Do.
1888....	Apr. 21–22	45.38	Jan. 6–7...........	1.70	Do.
1889....	June 30–July 1....	36.30	Oct. 28–29	2.30	Do.
1890....	Mar. 27	49.50	Aug. 15–17	10.50	Do.
1891....	Apr. 3–7	48.40	....	....	Do.

MISSISSIPPI RIVER, GREENVILLE, MISSISSIPPI.

[Zero of gauge, 108 feet above the Cairo datum plane.]

1844....	....	42.16	....	....	High-water mark, Mississippi River Commission levels.
1858....	....	43.00	....	....	Do.
1867....	....	39.92	....	....	Do.
1882....	Feb. 27............	41.68	Dec. 23–24.........	7.35	Mississippi River Commission gauge records.
1883....	Mar. 9–13	40.40	Oct. 4	5.60	Do.
1884....	Mar. 7–8	41.10	Dec. 14............	7.80	Do.
1885....	May 7–8............	38.05	Oct. 25	8.30	Do.
1886....	May 6	41.20	Nov. 15–17	4.20	Do.
1887....	Mar. 21–26	40.80	Nov. 22–24	1.85	Do.
1888....	Apr. 21–23	40.55	Jan. 6–7...........	2.60	Do.
1889....	July 1	31.85	Oct. 28–29	3.15	Do.
1890....	Mar. 17–18	43.45	Aug. 15–17	10.00	Do.
1891....	Apr. 2–3	43.25	....	....	Do.

MISSISSIPPI RIVER, REFUGE, MISSISSIPPI.

[Zero of gauge, 102.79 feet above the Cairo datum plane.]

1880....	Mar. 23–27	42.30	Nov. 6	3.50	Mississippi River Commission gauge records.
1881....	May 17–19	42.00	Sept. 20–21........	3.60	Do.

MISSISSIPPI RIVER, WILSON POINT, LOUISIANA.

[Zero of gauge, 93.45 feet above the Cairo datum plane.]

1884....	Mar. 23	37.81	Dec. 14............	6.50	Mississippi River Commission gauge record.

MISSISSIPPI RIVER, LAKE PROVIDENCE, LOUISIANA.

[Zero of gauge 89.62 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1862		40.87			Major Merrill (Chief of Engineers' Report, 1872, page 432.)
1867		39.99			Major Merrill (Chief of Engineers' Report, 1872, page 432. (A high-water mark, levels of Mississippi River Commission, makes this 39.31.)
1871			Dec. 31	−2.60	U. S. Engineer gauge records.
1872	May 1	35.15	Dec. 29	−3.85	Do.
1873	May 28	36.12	Nov. 4	0.91	Do.
1874	Mar. 21–23	37.37	Nov. 16	0.95	Do.
1875	Apr. 19–20	37.29	Nov. 12	5.90	Do.
1876	Apr. 12–14	37.95	Dec. 31	1.25	Do.
1877	May 6–7	35.82	Jan. 1–3	1.25	Do.
1878	Mar. 22–24	35.80	Oct. 27–28, Nov. 5–6	3.75	Do.
1879	Feb. 14–16	36.00	Oct. 16–17	0.55	Do.
1880	Apr. 3	38.05	Nov. 3	5.20	Do.
1881	Mar. 11	36.17	Sept. 14–19	3.00	Do.
1882	Mar. 20	38.32	Dec. 25	5.90	Do.
1883	Mar. 11–14	36.47	Oct. 2	4.20	Do.
1884	Mar. 23–24	38.40	Dec. 15	5.55	Do.
1885	May 10–11	35.55	Oct. 26	6.40	Do.
1886	May 7	37.91	Nov. 19	2.55	Do.
1887	Mar. 26	38.01	Nov. 22–24	1.52	Do.
1888	Apr. 24–25	38.10	Jan. 7–8	2.08	Do.
1889	July 1–2	29.40	Oct. 29–30	2.80	Do.
1890	Mar. 15	41.05	Aug. 17	8.50	Do.
1891	Apr. 1–4	41.00			Do.

MISSISSIPPI RIVER, HAY'S LANDING, MISSISSIPPI.

[Zero of gauge 86.05 feet above the Cairo datum plane.]

1882	Mar. 20	38.60			Mississippi River Commission gauge records.
1884	Mar. 24	38.72	Dec. 14	2.72	Do.

MISSISSIPPI RIVER, VICKSBURG, MISSISSIPPI.

[Zero of gauge 66.04 feet above the Cairo datum plane.]

1828		46.38			Humphreys and Abbot Report, page 172. Captain Willard (Ms., 1891.)
1844	June 28	46.18			Do.
1849	Apr. 26	46.38			Do.
1850	June 4	47.08			Captain Willard (Ms., 1891).
1855				−1.32	Do.
1858	June 26	46.98	Oct. 31	7.28	High water, Captain Willard (Ms., 1891.) Low water, Humphreys and Abbot Report, page 534. Corrected to present gauge by subtracting 1.32. Authority, Captain Willard (Ms., 1891).
59	Apr. 21	48.28			Captain Willard (Ms., 1891).
62	Apr. 27	51.10			Major Merrill (Chief of Engineers' Report, 1872, page 433). Captain Willard (Ms., 1891).
65		46.43?			Captain Willard (Ms., 1891). Major Abbot (Chief of Engineers' Report, 1869, page 337) gives this as 2.3 less than 1862.
7		49.02?			Captain Willard (Ms., 1891).
1			Dec. 31	−0.38	U. S. Engineer gauge records.
2	May 2–3	39.50	Dec. 30	−1.30	Do.
3	May 29–30	40.60	Jan. 1	2.35	Do.
4	May 2–5	45.70	Nov. 16–21	3.15	Do.

MISSISSIPPI RIVER, VICKSBURG, MISSISSIPPI—Continued.

[Zero of gauge 66.04 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1875	Apr. 21	43.00	Nov. 13–15	8.10	U. S. Engineer gauge records.
1876	May 10	44.90	Dec. 30–31	4.05	Do.
1877	May 8–13	41.60	Jan. 6–7	2.25	Do.
1878	Mar. 24–27	40.95			Do.
1879	Feb. 17	39.45			Do.
1880	Apr. 8–9	43.15	Oct. 27	7.70	Do.
1881	Mar. 10–12	41.85	Sept. 19–20	3.65	Do.
1882	Mar. 20–21	48.75	Dec. 26	7.60	Do.
1883	Apr. 7	43.80	Oct. 6	2.90	Do.
1884	Mar. 25	49.00	Dec. 15	4.85	Do.
1885	Feb. 3	42.40	Oct. 26–27	4.90	Do.
1886	May 7–9	44.15	Nov. 16	0.00	Do.
1887	Mar. 26–31	44.70	Nov. 24–25	—3.92	Do.
1888	Apr. 26	44.18	Jan. 7–8	—1.35	Do.
1889	July 3	34.45	Oct. 30–Nov. 1	—0.70	Do.
1890	Apr. 24–25	49.05	Aug. 17–24	9.00	Do.
1891	Apr. 2–4	48.10			Do.

MISSISSIPPI RIVER, ST. JOSEPH, LOUISIANA.

[Zero of gauge 52.74 feet above the Cairo datum plane.]

1881	Mar. 13	39.20			Mississippi River Commission gauge records.
1882	Mar. 20–21	44.90	Dec. 26	7.80	Do.
1883	Apr. 7	41.90	Oct. 8–9	4.20	Do.
1884	Mar. 23	44.98	Dec. 16	3.95	Do.
1885	Feb. 3	38.37			Do.
1889	July 3–4	†30.60	Oct. 30–Nov. 1	—3.95	Do.
1890	Apr. 23	45.15	Aug. 20–22	5.20	Do.
1891	Apr. 11	43.80			Do.

MISSISSIPPI RIVER, NATCHEZ, MISSISSIPPI.*

[Zero of gauge 36.89 feet above the Cairo datum plane.]

1871		43.80		1.20	Captain Benyaurd (Chief of Engineers' Report, 1876, page 613); Major Merrill (Chief of Engineers' Report, 1872, page 433).
1872	May 2, 4–5	39.85	Dec. 14–16	0.00	U. S. Engineer gauge records.
1873	May 30	40.15	Jan. 1	0.95	Do.
1874	Apr. 20	45.60	Nov. 17	2.70	Do.
1875	Apr. 25–26	41.85	Jan. 1	7.00	Do.
1876	May 15–16	43.85	Dec. 31	2.90	Do.
1877	May 30–31	40.70	Jan. 9	1.40	Do.
1878	Mar. 28	39.20	Nov. 8	6.35	Do.
1879	Feb. 17–20	36.80	Oct. 18–22	1.80	Do.
1880	Apr. 16	43.50	Oct. 28	7.30	Do.
1881	Mar. 16, 19	40.80	Sept. 21–22	4.70	Do.
1882	Mar. 28–29	47.75	Nov. 6–9	9.70	Do.
1883	Apr. 7–9	44.00	Oct. 6	4.90	Do.
1884	Mar. 24–26	47.40	Oct. 1–2	7.70	Do,
1885	Feb. 3–5	42.60	Oct. 27	6.50	Do.
1886	May 9–11	43.75	Nov. 6	2.80	Do.
1887	Mar. 30–Apr. 3	44.20	Nov. 25–27	0.75	Do.
1888	Apr. 27–May 1	43.40	Jan. 7	4.50	Do.
1889	Mar. 12–13	34.15	Nov. 3–5	2.70	Do.
1890	Apr. 23	48.60	Aug. 19–21	11.60	Do.
1891	Apr. 11–12	46.50			Do.

* See note B, page 3555.

MISSISSIPPI RIVER, RED RIVER LANDING, LOUISIANA.

[Zero of gauge 23.85 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1867		46.30			Major Merrill (Chief of Engineers' Report, 1872, page 434). Corrected by adding 3 feet (Captain Benyaurd, Chief of Engineers' Report, 1876, page 614).
1871		44.50	Dec. 31	†2.00	High water, Major Merrill, as above. Low water, U. S. Engineer gauge record.
1872	May 6	39.42	Dec. 15	0.00	U. S. Engineer gauge records.
1873	June 12	39.02	Jan. 1	4.50	Do.
1874	Apr. 16	47.05	Nov. 22	1.90	Do.
1875	May 3	40.45	Jan. 1	6.00	Do.
1876	May 15	45.41	Dec. 30	2.23	Do.
1877	June 1-3	40.55	Jan. 8, 10	0.85	Do.
1879	Feb. 19-20	35.90	Oct. 24-25	0.55	Do.
1880	Apr. 22-24	44.05	Oct. 26-27	6.10	Do.
1881	Apr. 6-9	40.10	Sept. 21-22	3.40	Do.
1882	Mar. 27	48.53	Oct. 18	9.10	Do.
1883	Apr. 9	45.20	Oct. 7-8	3.95	Do.
1884	Mar. 29-31	47.30	Oct. 1-2	6.30	Do.
1885	Feb. 5-6	41.96	Oct. 26	6.70	Do.
1886	May 31	41.94	Nov. 7	2.70?	Do.
1887	Apr. 8	43.00	Nov. 25	0.46	Do.
1888	Apr. 30	41.75	Oct. 23-24	3.90?	Do.
1889	Mar. 13	34.00	Nov. 4-5	2.40?	Do.
1890	Apr. 23	48.67	Aug. 23-24	8.80	Do.
1891	Apr. 26-May 4	45.48			Do.

MISSISSIPPI RIVER, BAYOU SARA, LOUISIANA.

[Zero of gauge 23.95 feet above the Cairo datum plane.

1889	Mch. 13-14	28.00	Nov. 3-5	−2.10	Mississippi River Commission gauge records.
1890	Apr. 21	41.20	Aug. 30-Sept. 1	4.00	Do.
1891	Apr. 29-May 6	38.80			Do.

MISSISSIPPI RIVER, PORT HICKEY, LOUISIANA.

[Zero of gauge 13.68 feet above the Cairo datum plane.]

1881	Apr. 5-7	40.80	Sept. 11	9.50	Mississippi River Commission gauge records.
1882	Mch. 27-29	47.90			Do.
1883	Apr. 9	46.10			Do.
1884	Mch. 29	47.45	Dec. 3	13.10	Do.
1885	Jan. 31-Feb. 7	42.80			Do.

MISSISSIPPI RIVER, BATON ROUGE, LOUISIANA.*

[Zero of gauge 20.06 feet above the Cairo datum plane.]

1[illegible]	Apr. 1	34.53	Nov. 24	3.20	Major Merrill (Chief of Engineers' Report, 1874, page 491).
1[illegible]				0.20	Do.
1[illegible]		36.07			Do.
1[illegible]		34.49			Do.
1[illegible]		34.52			Do.
1[illegible]	May 7	29.65	Dec. 22	1.15	U. S. Engineer gauge records.
1[illegible]	June 17	29.85	Jan. 1	2.32	Do.

* See note B, page 3555.

MISSISSIPPI RIVER, BATON ROUGE, LOUISIANA*—Continued.

[Zero of gauge 21.06 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		Feet.	
1874	Apr. 16	36.15	Nov. 21	2.30	U. S. Engineer gauge records.
1875	May 13	29.75	Jan. 1	3.95	Do.
1876	May 8, 15-16*	33.40	Dec. 30-31	1.70	Do.
1877	June 1, 4	29.65	Jan. 9	0.90	Do.
1878	May 19	29.35	Nov. 6	3.30	Do.
1879	Feb. 15-17	26.10	Nov. 21-24	2.00	Do.
1880	Apr. 22-24	33.20	Oct. 13-15, 25-26	4.00	Do.
1881	Apr. 8	30.05	Sept. 22	2.90	Do.
1882	Mch. 26	35.95	Oct. 18	6.18	Do.
1883	Apr. 9	35.08	Oct. 7	3.10	Do.
1884	Mch. 24	36.20	Oct. 2	4.30	Do.
1885	Jan. 30-31, Feb. 2	31.90	Oct. 31	4.65	Do.
1886	May 31-June 2	32.10	Nov. 20	2.25	Do.
1887	Apr. 10	33.55	Nov. 26	1.10	Do.
1888	Apr. 29, May 3	32.50	Jan. 10	2.90	Do.
1889	Mar. 13-14	26.75	Oct. 27-28	2.50	Do.
1890	Apr. 21-22	36.60	Aug. 22-24	5.45	Do.
1891	May 3, 5	35.55			Do.

* See note B, page 3555.

MISSISSIPPI RIVER, PLAQUEMINE, LOUISIANA.

[Zero of gauge 21.06 feet above the Cairo datum plane.]

1880	Apr. 23-25	29.00?			Mississippi River Commission gauge records.
1881	Apr. 8-9	26.00?	Sept. 21-22	1.70?	Do.
1882	Mar. 21-27	31.30?	Oct. 15-18, Nov. 8-11.	3.80?	Do.
1883	Apr. 9	30.80	Oct. 7	1.35	Do.
1884	Mar. 24	31.70	Oct. 1-2	2.90	Do.
1885	Jan. 30-Feb. 5	27.70			Do.
1889	Mar. 13-14	23.00	Oct. 30	1.10	Do.
1890	Apr. 22	31.90	Aug. 22-23	3.65	Do.
1891	Apr. 15-22	31.05			Do.

MISSISSIPPI RIVER, DONALDSONVILLE, LOUISIANA.*

[Zero of gauge 19.14 feet (preliminary value) above the Cairo datum plane.]

1890			Aug. 21-22	4.14	U. S. Engineer gauge records.
1891	Mar. 18, 20	27.90			Do.

* See note B, page 3555.

MISSISSIPPI RIVER, COLLEGE POINT, LOUISIANA.

[Zero of gauge 21.24 feet above the Cairo datum plane.]

1880	Apr. 18, 20-23	21.30	Nov. 2	2.65	Mississippi River Commission gauge records.
1881	May 22-24	19.95	Aug. 27, Sept. 19	1.35	Do.
1882	Mar. 26	23.20	Oct. 18, Nov. 7	2.45	Do.
1883	Apr. 9	23.45	Oct. 12-13	1.40	Do.
1884	Mar. 24	24.10	Dec. 2	1.25	Do.
1885	Jan. 30, Feb. 1	21.10			Do.
1889	Mar. 12-14	17.48	Oct. 28	0.20	Do.
1890	Mar. 16	23.90	Aug. 22	2.22	Do.
1891	Mar. 31	23.05			Do.

MISSISSIPPI RIVER, CARROLLTON, LOUISIANA.

[Zero of gauge 20.91 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		Feet.	
1828	Apr. 1	15.2			Humphreys and Abbot Report page 172.
1844		14.5			Do.
1849	Mar. 11–15	15.2	Oct. 6	2.1	Humphreys and Abbot Report, page 516.
1850	Jan. 21, 28, 30, Feb. 2.	13.8	Nov. 18	–0.5	Humphreys and Abbot Report, page 517.
1851	Mar. 27–30	15.4	Nov. 24	0.2	Humphreys and Abbot Report, page 521.
1852	May 30	14.1	Feb. 4	0.6	Humphreys and Abbot Report, page 525.
1853	May 30–31, June 2–3.	15.0?	Oct. 26	1.2?	Humphreys and Abbot Report, page 527.
1854	Apr. 14	14.7?	Dec. 30	0.0?	Humphreys and Abbot Report, page 528.
1858	May 10, 12	15.1	Nov. 5, 7–9	0.4	Humphreys and Abbot Report, page 536.
1859	May 2, 4, 6	15.6	Nov. 13	–0.4	Humphreys and Abbot Report, page 540.
1860	Feb. 6	13.4	Oct. 18	–0.7	Humphreys and Abbot Report, page 541.
1862		15.9			Major Abbot, Chief of Engineers' Report, 1869, page 337, and 1875, page 568.
1871		15.4			Major Merrill, Chief of Engineers' Report, 1872, page 434.
1872	May 6	12.30	Dec. 27	–1.60	U. S. Engineer gauge records.
1873	June 3–4	12.93	Nov. 20	0.08	Do.
1874	Apr. 16	15.70	Nov. 24	0.10	Do.
1875	May 3–5, 14–16, 18	11.30	Nov. 13	0.10	Do.
1876	May 11	12.70	Dec. 30	–1.20	Do.
1877	June 4, 8	11.10	Jan. 9	–1.40	Do.
1878	Mar. 21	11.30	Nov. 22	–0.10	Do.
1879	Feb. 20, 22	10.80	Nov. 24	0.80	Do.
1880	Apr. 22, 24	13.90	Nov. 2	0.30	High water, Mississippi River Commission discharge party gauge records. Low water, U. S. Engineer gauge records.
1881	Apr. 12	12.55	Sept. 10.	0.30	U. S. Engineer gauge records.
1882	Mar. 27	14.95	Nov. 8	1.00	Do.
1883	Apr. 7	15.40	Oct. 15	0.50	Do.
1884	Mar. 18	15.50	Dec. 2, 5	0.30	Do.
1885	Jan. 22, 23	13.55	Oct. 24	0.90	Do.
1886	May 31	13.80	Nov. 27	–0.40	Do.
1887	Apr. 6–9	14.50	Nov. 20	–0.70	Do.
1888	Apr. 26	14.70	Jan. 10	–0.20	Do.
1889	Mar. 13–14	11.60	Nov. 9, 11	0.40	Do.
1890	Mar. 13–17	16.10	Aug. 11	1.60	Do.
1891	Mar. 16	16.00			Do.

ARKANSAS RIVER, LITTLE ROCK, ARKANSAS.

[Zero of gauge, 241.55 feet (preliminary value) above the Cairo datum plane.]

1857		31.00			Major Merrill, Chief of Engineer's Report, 1872, page 432.
1872	May 20–21	26.00	Dec. 4–5, 14, 15	0.80	U. S. Engineer gauge records.
1873	Apr. 12	22.60	Sept. 23, 26	0.40	Do.
1874	Apr. 25	23.00	Sept. 4–7	0.00	Do.
1875	Aug. 5	21.80	Nov 27	0.50	Do.
1876	July 7	26.30	Oct. 18	1.00	Do.
1877	June 13	27.50			
1878	May 28	24.30			
879	Feb. 3	16.60	Oct. 23–24.	1.00	Do.
880	Mar. 15	14.80	May 29–30	0.80	Do.
81	Feb. 20	18.40	Jan. 15–18	1.00	Do.
82	Feb. 25	25.70	Sept. 23–26	3.30	Do.
83	Feb. 19	25.80	Oct. 8–9, 12–13	4.90	Do.
84	Feb. 15	30.60	Nov. 17–21	4.80	Do.
85	Apr. 27–29	28.60	Dec. 8, 24–29	4.40	Do.
86	Feb. 16	17.90	Nov. 8–9, 16	3.20	Do.
87	May 6	17.60	Nov. 20	2.00	Do.
88	May 23	20.30	Oct. 19–Nov. 6	3.40	Do.
89	Mar. 27	23.30	Oct. 29	3.90	Do.
90	Apr. 29	26.80	Aug 17–19	4.50	Do.
91	Apr. 24	22.70			Do.

OUACHITA RIVER, CAMDEN, ARKANSAS.

[Zero of gauge 96.69 feet (preliminary value) above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		Feet.	
1882		46.0			U. S. Signal Service.
1885			Dec. 8	†3.4	U. S. Signal Service gauge records.
1886	Nov. 27	26.8	Sept. 12-13	2.8	Do.
1887	Dec. 13	35.7	Aug. 29-30	1.8	Do.
1888	Jan. 18	34.2	Oct. 16-21	2.3	Do.
1889	Jan. 21	37.7	Oct. 25-30	2.3	Do.
1890	Apr. 7	38.5	Aug. 6	3.5	Do.
1891	Feb. 5	35.6			U. S. Engineer gauge records.

OUACHITA RIVER, MONROE, LOUISIANA.

[Zero of gauge 51.55 feet (preliminary value) above the Cairo datum plane.]

1874		49.1			U. S. Signal Service.
1882		48.9			Do.
1884			Sept. 21-27	0.92	U. S. Signal Service gauge records.
1885	Jan. 19	48.3	Oct. 18-28	0.9	Do.
1886	May 24	30.1	Sept. 11-13	1.0	Do.
1887	Mar. 31-Apr. 4	33.6	Oct. 17-23	0.1	Do.
1888	Apr. 6-13	34.2	Oct. 13-23	0.8	Do.
1889	Feb. 9-14	34.0	Oct. 29, Nov. 6	0.9	Do.
1890	May 14-15	43.2	Sept. 12-13	2.2	Do.

RED RIVER, FULTON, ARKANSAS.

[Zero of gauge 244.78 feet above the Cairo datum plane.]

1876	July 17	35.75			U. S. Signal Service gauge records.
1885			Dec. 16	3.4	Do.
1886	Apr. 21	20.9	Aug. 4-7, Sept. 10-11, 25.	3.3	Do.
1887	Dec. 12	27.5	Sept. 7	0.6	Do.
1888	May 7	31.8	Nov. 1-3	3.4	Do.
1889	Jan. 20	30.8	Oct. 28-31	4.0	Do.
1890	May 3	34.0	Aug. 16-19	4.35	U. S. Engineer gauge records.
1891	Apr. 27-28	30.3			Do.

RED RIVER, GARLAND, ARKANSAS.

[Zero of gauge 223.44 feet above the Cairo datum plane.]

1885		28.34			Captain Willard (gauge inspection report, 1890).
1890	Apr. 30	28.17	Aug. 17-18	2.86	U. S. Engineer gauge records.
1891	Apr. 28	26.84			Do.

RED RIVER, SHREVEPORT, LOUISIANA.

[Zero of gauge 161.27 feet (preliminary value) above the Cairo datum plane.]

1873	June 8-9	25.5	Sept. 28	1.4	U. S. Signal Service gauge records.
1874	Apr. 29-May 1	27.9	Sept. 6-7	-1.2	Do.
1875	Apr. 22	25.8	Nov. 22-23	5.2	Do.
1876	July 28	31.9	Nov. 13	5.2	Do.
1877	May 11-12	29.8	Oct. 15	5.0	Do.
1878	Jan. 31	28.4	Nov. 21	3.5	Do.
1879	May 16-17	24.9	Nov. 1-4	0.0	Do.
1880	Apr. 4	23.2	Oct. 28-29	4.5	Do.
1881	Mar. 7	27.8	Sept. 1-2	-1.4	Do.
1882	Feb. 21	31.4	July 30	8.0	Do.
1883	Mar. 11-12	25.3	Oct. 16-17	0.7	Do.
1884	May 14	32.7	Sept. 24	-0.2	Do.
1885	May 11-12	30.5	Oct. 24	0.7	Do.
1886	Apr. 29	18.8	Sept. 12	-1.0	Do.
1887	Dec. 24-25	21.6	Sept. 8-11	-0.6	Do.
1888	May 19	30.3	Nov. 4-6	0.6	Do.
1889	Feb. 3	31.9	Sept. 4, 10	4.3	Do.
1890	May 8	34.7	Aug. 22-24	0.2	U. S. Engineer gauge records.
1891	Feb. 12-13	25.2			Do.

RED RIVER, ALEXANDRIA, LOUISIANA.

[Zero of gauge 64.46 feet above the Cairo datum plane.]

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1849		35.36			Major Merrill, Chief of Engineers' Report, 1873, page 521.
1866		36.46			Do.
1872	Apr. 29–May 1	33.30	Dec. 7–12	—2 60	U. S. Engineer gauge records.
1873	June 19–20	30.20	Sept. 24	0.00	Do.
1874	May 8–10	34.90	Sept. 26, 28	—2.00	Do.
1875	Apr. 27	23.90	Nov. 22–23	—2.20	Do.
1876	Apr. 17	32.80	Nov. 16–24	—1.90	Do.
1877	May 18–19	25.45	Oct. 14–15	—2.60	Do.
1878	Mar. 13	27.1†	Nov. 24	—2.60	Do.
1879	May 26	19.20	Nov. 1–5	—3.10	Do.
1880	Apr. 11–13	21.80	Oct. 27–30	—1.60	Do.
1881	Mar. 20	27.85	Sept. 29	—3.70	Do.
1882	Mar. 17–19	34.85	Oct. 8	1.25	Do.
1883	Mar. 27	25.45	Oct. 19, 21–22	—2.30	Do.
1884	June 1, 5, May 30–31.	35.25	Nov. 3–5	—1.90	Do.
1885	Jan. 25	34.30	Oct. 24	—2.05	Do.
1886	June 17	27.90	Sept. 11–13	—3.20	Do.
1887	Dec. 28–29	19.30	Sept. 14–16	—3.00	Do.
1888	Mar. 27–28	29.60	Nov. 7	—3.25	Do.
1889	Feb. 13	31.50	Sept. 13–14	0.25	Do.
1890	May 19	36.85	Aug. 21	—3.10	Do.
1891	Feb. 16–17	29.95			Do.

ST. FRANCIS RIVER, WITTSBURG, ARKANSAS.

Year.	Highest Day.	Gauge reading.	Lowest Day.	Gauge reading.	Authority.
1884			Nov. 19	—1.66	Mississippi River Commission gauge record.
1885	Jan. 26	20.37	Oct. 10	—2.55	Do.
1886	Apr. 28	42.02	Sept. 25	—2.53	Do.
1887	Mar. 19–20	38.92	Oct. 29–31	—2.90	Do.
1888	Apr. 24	26.70	Oct. 19	—2.70	Do.
1889	Jan. 30	12.51	Nov. 6–7	—2.48	Do.
1890	Mar. 26–27	40.15	Sept. 27	—3.24	Do.
1891	Mar. 21	36.98			Do.

TENNESSEE RIVER, CHATTANOOGA, TENNESSEE.

Year.	Highest Day.	Gauge reading.	Lowest Day.	Gauge reading.	Authority.
1867	Mar. 11	58.05			U. S. Signal Service gauge records.
1874			Nov. 7–8	0.67	Do.
1875	Mar. 1	54.00	Oct. 27–31	2.17	Do.
1876	Jan. 1	31.08	Oct. 18–20	1.00	Do.
1877	Apr. 11	28.07	Oct. 5	1.17	Do.
1878	Feb. 25	19.17	Sept. 14–15	0.92	Do.
1879	Jan. 15	38.00	Oct. 6, 7, 9–10	0.17	Do.
1880	Mar. 18	38.83	Oct. 16. 24, 27–28, 30	1.00	Do.
1881	Feb. 13	22.42	Sept. 11–14	0.00	Do.
1882	Jan. 19	40.17	Oct. 18, Nov. 11–12	1.67	Do.
1883	Jan. 23	38.17	Sept. 19	0.00	Do.
1884	Mar. 10	42.83	Oct. 19–21	0.17	Do.
1885	Nov. 9	30.40	Sept. 20	0.70	Do.
1886	Apr. 3	52.20	Oct. 23–26	1.20	Do.
[illegible]	Feb. 28–Mar. 1	27.80	Oct. 15–17	1.20	Do.
[illegible]	Mar. 31	27.00	July 29	1.80	Do.
[illegible]	Feb. 18	29.60	Oct. 22–24	2.10	Do.
[illegible]	Mar. 2	42.50	July 17	2.00	Do.

TENNESSEE RIVER, FLORENCE, ALABAMA.

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1867		31.1			Major Merrill (Chief of Engineers' Report, 1872, page 430).
1871				0.0	U. S. Engineer gauge records.
1872	Dec. 25	16.35	Oct. 24, 28	−0.76	Do.
1873	Feb. 22	22.90	Oct. 21–23	−0.45	Do.
1874	Apr. 17	26.00	Nov. 10	0.02	Do.
1875	Mar. 8	29.38	Nov. 8	0.43	Do.
1876	Jan. 4	19.78	Oct. 21	−0.56	Do.
1877	Apr. 10	19.35	Aug. 28	−0.03	Do.
1878	Apr. 26	13.55	Sept. 18	−0.76	Do.
1879	Jan. 20	21.45	Oct. 6	−0.50	Do.
1880	Mar. 18	24.50	Oct. 22–23, 27	0.05	Do.
1881	Mar. 21	17.40	Sept. 14	0.08	Do.
1882	Jan. 22	29.60	Nov. 15–16	1.15	Do.
1883	Jan. 28	23.30	Sept. 13–26	0.40	Do.
1884	Mar. 14–15	25.20	Oct. 24–28	0.25	Do.
1885	Jan. 20	17.80	Sept. 20–22	0.55	Do.
1886	Apr. 8	28.10	Oct. 15–Nov. 1, Nov. 10–13.	0.50	Do.
1887	Feb. 27–Mar. 1	17.50	Sept. 21–26, 28–29, Oct. 12–23.	0.50	Do.
1888	Mar. 29	20.75	July 31, Aug. 4	0.70	Do.
1889	Feb. 20–21	19.70	May 28–29	0.15	Do.
1890	Mar. 2–3	23.30	July 19–20	1.70	Do.
1891	Mar. 15	22.20			Do.

WABASH RIVER, MOUNT CARMEL, ILLINOIS.

Year.	Highest day.	Gauge reading.	Lowest day.	Gauge reading.	Authority.
1884			Sept. 16–17, 20–21	†1.1	U. S. Signal Service gauge records.
1885	Jan. 6	24.7	Sept. 11–12	2.0	Do.
1886	May 22	19.8	Sept. 20–21, Nov. 9–12.	1.4	Do.
1887	Mar. 14	22.0	Sept. 25–29, Oct. 30–Nov. 24.	0.6	Do.
1888	Apr. 4–5	20.6	Sept. 22, Oct. 5–22	1.0	Do.
1889	June 18	21.4	Oct. 16–23	0.9	Do.
1890	Jan. 13–15	25.1	Aug. 16–21	1.4	Do.

WHITE RIVER, JACKSONPORT, ARKANSAS.

Year.	Highest day.	Gauge reading.	Lowest day.	Gauge reading.	Authority.
1867		32.83			Major Merrill (Chief of Engineers' Report, 1872, page 431).
1871				0.00	Do.
1872	May 24	22.00	Dec. 24	−1.10	U. S. Engineer gauge records.
1873	Apr. 13	30.00	Sept. 2	−0.70	Do.
1874	Apr. 23	31.05	Nov. 3–4	−0.50	Do.
1875	May 6	26.80	Oct. 29	−0.03	Do.
1876	Jan. 31	31.65	Dec. 28	0.50	Do.
1877	June 13	26.40	Oct. 7	0.20	Do.
1878			Nov. 14	0.32	Do.
1879	Feb. 8	12.32	Nov. 3–7	−0.60	Do.
1880	Mar. 12	27.10	Sept. 13–14, 17–18, Oct. 9.	0.20	Do.
1881	Feb. 22	27.10	Aug. 28, Sept. 21	1.00	Do.
1882	May 11	31.20	Aug. 29–30, Sept. 5–6.	1.20	Do.
1883	Feb. 19	32.00	Sept. 23	1.20	Do.
1884	Feb. 15	32.80	Nov. 11–17	0.60	Do.
1885	Jan. 2	30.90	Sept. 2–7, Oct. 24, Nov. 3–4, Dec. 8.	0.80	Do.
1886	May 12	24.00	Sept. 9–11, Nov. 1–2	0.20	Do.
1887	May 7	25.30	Nov. 19–23	−0.40	Do.
1888	May 23	26.90	Aug. 10–11, Oct. 11–22.	0.30	Do.
1889	Mar. 27–28	24.00	Oct. 23–30	0.80	Do.
1890	Mar. 14	33.35	Aug. 9–10	2.40	Do.
1891	Apr. 26	23.75			Do.

WHITE RIVER, CLARENDON, ARKANSAS.

Year.	Highest.		Lowest.		Authority.
	Day.	Gauge reading.	Day.	Gauge reading.	
		Feet.		*Feet.*	
1884			Nov. 19–20	6.20	Mississippi River Commission gauge records.
1885	Jan. 8	33.58	Oct. 27–31	5.98	Do.
1886	May 4	29.20	Nov. 12–13	5.35	Do.
1887	Mar. 22	27.90	Nov. 22–23	4.06	Do.
1888	Apr. 8–9	25.70	Aug. 15	5.88	Do.
1889	Apr. 11	29.10	Oct. 31–Nov. 1	6.60	Do.
1890	Mar. 20	36.63	Aug. 12	8.74	Do.
1891	Mar. 19	29.10			Do.

YAZOO RIVER, YAZOO CITY, MISSISSIPPI.

[Zero of gauge 93.92 feet above the Cairo datum plane.]

1875				-4.3	U. S. Signal Service.
1882		36.5			Do.
1884			Nov. 22	-1.21	Mississippi River Commission gauge records.
1885	Feb. 5–7	22.82	Sept. 8	-2.35	Do.
1886	May 11–12	22.40	Nov. 8–10	-0.95	Do.
1887	Mar. 22–28	23.80	Nov. 23	-2.30	Do.
1888	Apr. 26–28	23.90	Aug. 15	-0.20	Do.
1889	Mar. 9–11	18.50	Oct. 30–Nov. 1	-1.92	Do.
1890	Apr. 26–27	28.82	Aug. 27	0.00	Do.
1891	Mar. 8	28.98			Do.

APPENDIX C 10.

REPORT OF MR. J. A. OCKERSON, ASSISTANT ENGINEER, ON CHANGES IN THE BED OF MISSISSIPPI RIVER NEAR THE HEAD OF THE PASSES.

OFFICE MISSISSIPPI RIVER COMMISSION,
St. Louis, Mo., June 17, 1891.

CAPTAIN: I submit herewith the results of an investigation as to changes in the bed of the Mississippi River a short distance above the Head of the Passes. The shaded part of the accompanying sketch shows the location of the area examined.

The appended table shows the maximum depths and mean depths and the widths of the 26 and 30 foot depths on 3 sections, as derived from annual surveys made from 1880 to 1890 inclusive. It also shows the mean depth of the whole area for each of the above years. These mean depths are derived from soundings on 14 sections, which include the fixed sections, whose values are given separately.

The soundings are all reduced to a stage of 2.4 feet on Head of Passes gauge.

The maximum depths on the lower section lie near the entrance to South Pass.

This investigation does not develop any law of change. It does not show that there is a progressive tendency to shoaling, nor is there an invariable effort to increase the depth.

The scours and fills alternate without any apparent regularity. If we compare the first five years with the last five we find an average deepening for the last period of 0.6 feet.

The increase in the maximum depth of section 1–0 during the last three years was ite marked.

he data from which the deductions were made were derived from the surveys of istant Engineer C. Donovan, published in the Annual Reports of the Chief of gineers.

Very respectfully, your obedient servant,

J. A. OCKERSON,
Assistant Engineer.

apt. CARL F. PALFREY,
Corps of Engineers, U. S. A.,
Secretary Mississippi River Commission.

Changes in depth at Head of Passes, as derived from analysis of the annual surveys of C. Donovan, U. S. Assistant Engineer.

[See Reports of Chief of Engineers.]

Office Mississippi River Commission, November 15, 1890, J. A. Ockerson, assistant engineer.

Date.	Carrollton gauge.	Section Cubitts. Depth. Maximum.	Section Cubitts. Depth. Mean.	Section Cubitts. Width. 26 feet depth.	Section Cubitts. Width. 30 feet depth.	Section G—H. Depth. Maximum.	Section G—H. Depth. Mean.	Section G—H. Width. 26 feet depth.	Section G—H. Width. 30 feet depth.	Section I—J. Depth. Maximum.	Section I—J. Depth. Mean.	Section I—J. Width. 26 feet depth.	Section I—J. Width. 30 feet depth.	Mean depth of whole shaded area.
				Feet.	*Feet.*			*Feet.*	*Feet.*			*Feet.*	*Feet.*	*Feet.*
June 5-7, 1880	8.4	32.8	25.2	......	1,430	31.4	27.4	4,660	925	33.8	28.1	4,260	1,100	26.[illegible]
June 6-9, 1881	12.2	36.5	27.3	......	2,030	35.6	26.5	4,650	1,930	35.4	28.2	4,858	920	27.2
June 3-5, 1882	12.4	35.3	25.7	4,400	2,870	34.4	27.5	4,650	1,712	36.8	27.5	3,890	2,218	27.4
June 15-17, 1883	14.1	40.3	28.2	3,870	3,120	40.2	27.9	4,130	3,203	42.0	28.7	5,690	2,910	28.2
May 10-20, 1884	13.6	37.1	26.1	4,260	2,280	35.6	26.9	4,740	2,100	45.0	27.8	5,310	2,490	27.0
May 4-8, 1885	12.4	33.8	24.9	4,380	1,400	33.7	26.1	4,140	1,470	38.5	26.7	4,035	755	26.0
April 19-21, 1886	12.7	34.9	26.1	4,950	2,600	33.3	27.5	5,440	1,360	42.8	28.1	5,115	1,240	27.1
April 13-19, 1887	14.2	38.0	28.8	4,518	3,140	37.1	27.4	4,630	3,110	44.5	27.9	6,180	3,670	28.0
April 2-5, 1888	11.7	35.0	26.2	4,615	2,890	34.0	26.9	4,990	2,610	63.5	28.2	5,530	1,305	27.0
March 26-29, 1889	9.2	33.3	27.6	4,090	2,820	32.4	27.7	4,230	2,910	66.0	27.8	4,850	1,000	27.4
March 17-25, April 4-8, 1890	15.5	39.0	29.4	4,600	3,550	39.0	28.7	5,175	3,825	69.0	30.6	5,600	3,300	29.2

COMMERCIAL STATISTICS.

Registered tonnage plying on the Lower Mississippi River, reported by custom-houses in Pittsburg, Cincinnati, and St. Louis.

Name of steamer or line.	Where enrolled.	Measured tonnage.
Steamer.		
Sam Brown	Pittsburg, Pa	474.10
Charles Brown	...do	544.12
Alice Brown	...do	551.36
Tom Rees No. 2	...do	327.02
Jim Wood	...do	402.12
S. L. Wood	...do	514.85
John A. Wood	...do	687.52
Raymond Horner	...do	688.58
Annie Roberts	...do	342.86
John Moran	...do	220.51
George Shiras	...do	140.27
Time	...do	382.36
Crescent	...do	239.96
Diamond	...do	291.36
Jos. B. Williams	...do	301.91
Dick Fulton	...do	357.53
W. W. O'Neil	...do	778.96
Samuel Clarke	...do	435.82
Coal City	...do	361.94
Jos. Walton	...do	300.27
J. F. Walton	...do	485.04
Jos. Nixon	...do	307.71
Fred Wilson	...do	408.98
Smoky City	...do	549.36
Tom Dodsworth	...do	500.35
Josh Cook	...do	384.59
Ed. Roberts	...do	263.89
Pacific	...do	212.91
Coal Valley	...do	352.44
Boaz	...do	623.30
Hornet No. 2	...do	289.05
New South	Cincinnati, Ohio	846.55
Ohio	...do	716.40
Buckeye State	...do	669.92
U. P. Schenck	...do	1,178.89
Guiding Star	...do	1,121.91
Golden Rule	...do	881.27
New Mary Houston	...do	1,163.93

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Registered tonnage plying on the Lower Mississippi River, etc.—Continued.

Name of steamer or line.	Where enrolled.	Measured tonnage.
Line.		
St. Louis and New Orleans Anchor Line	St. Louis, Mo	14,619.49
Helena and Saint Louis Transportation Company	do	1,985.92
Cherokee Packet Company	do	1,531.78
St. Louis and Mississippi Valley Transportation Company	do	85,981.12
Cape Girardeau Transportation Company	do	1,340.01
Grand total		125,257.73

Shipments by New Orleans boats and barges for three years.

Articles.		1890.	1889.	1888.
Apples	bbls	348	427	972
Ale and beer	pkgs	2,503	2,258	1,772
Bagging	pieces	38,276	78,731	18,575
Barley	sacks	39	5	10
Barley	bush			
Barbed wire	lbs	1,831,163	550,343	118,512
Butter	do	9,377	3,014	9,145
Bran	sacks	70,746	75,821	79,761
Cattle	head	5	41	38
Corn	sacks	152,903	161,252	191,397
Corn in bulk	bush	8,717,850	12,898,955	5,844,042
Corn meal	bbls	133,697	125,979	90,752
Cotton	bales	2,054	801	
Cotton-seed meal	tons			
Eggs	pkgs	2		
Flour	bbls	330,300	297,980	313,327
Hay	tons	956	2,214	3,359
Horses and mules	head	704	536	432
Hogs	do	24	5	20
Hominy and grits	bbls	40,247	26,400	21,550
Pork	do	6,279	4,956	3,111
Hams	lbs	131,926	127,340	107,290
Meats	do	1,789,865	2,135,711	1,739,576
Lard	do	8,116,580	7,969,345	6,595,134
Malt	sacks	15,845	9,235	27,998
Oats	do	403,173	407,874	364,242
Oats in bulk	bush	89,960	89,707	160,584
Onions	pkgs	153	127	426
Potatoes	do	656	587	938
Rye	sacks	1,036	50	144
Rye in bulk	bush		17,432	
Sheep	head			
Tallow	lbs	220		26,000
Tobacco	hhds			
Tobacco, manufactured	lbs	36,757	30,185	51,014
Wheat	sacks	418	241	1,120
Wheat in bulk	bush	1,409,440	1,651,950	1,247,952
Whisky	bbls	1,046	1,018	1,052
White lead	lbs	1,184,295	1,867,378	1,924,637
Merchandise and sundries	pkgs	189,651	178,480	180,418
Total tons		418,400	518,380	325,403

Shipments by Memphis, Vicksburg, and Natchez boats for 3 years.

Articles.		1890.	1889.	1888.
Apples	bbls	2,926	4,221	4,351
Ale and beer	pkgs	33,127	33,434	9,011
Bagging	pieces	40,349	70,454	18,340
Barley	sacks	577	237	151
Barley	bush	....	....	....
Barbed wire	lbs	879,045	949,598	389,057
Butter	lbs	94,761	79,656	108,166
Bran	sacks	39,533	57,889	28,882
Cattle	head	77	29	76
Corn	sacks	119,403	98,730	66,368
Corn in bulk	bush	....	....	....
Corn meal	bbls	201,964	172,931	111,141
Cotton	bales	....	....	....
Cotton-seed meal	tons	....	....	....
Eggs	pkgs	270	....	13
Flour	bbls	173,970	178,713	173,606
Hay	tons	3,488	3,290	2,064
Horses and mules	head	1,834	1,505	1,335
Hogs	head	181	266	99
Hominy and grits	bbls	4,778	3,006	3,303
Pork	bbls	7,507	7,894	7,724
Hams	lbs	791,112	602,447	916,666
Meats	lbs	13,606,078	7,377,798	5,955,912
Lard	lbs	1,338,629	1,571,846	2,098,792
Malt	sacks	362	40	150
Oats	sacks	123,234	112,348	60,319
Oats in bulk	bush	....	....	....
Onions	pkgs	2,246	3,211	5,339
Potatoes	pkgs	13,365	12,153	13,882
Rye	sacks	1,378	427	510
Rye in bulk	bush	....	....	....
Sheep	head	6	....	....
Tallow	lbs	....	....	....
Tobacco	hhds	....	....	2
Tobacco, manufactured	lbs	489,363	360,329	378,997
Wheat	sacks	173	384	490
Wheat in bulk	bush	....	....	....
Whisky	bbls	2,909	2,546	2,517
White lead	lbs	536,637	646,503	604,324
Merchandise and sundries	pkgs	1,091,650	1,036,339	618,395
Total tons		125,405	114,815	82,715

Shipment of bulk grain by barges to New Orleans during 1890.

Date.		Name of towboat.	Corn.	Wheat.	Oats.	Bulk grain.	Other freight.	Total.
			Bush.	*Bush.*	*Bush.*	*Tons.*	*Tons.*	*Tons.*
Jan.	4	My Choice and barges	64,161	32,300	....	2,700	....	2,700
	6	E. M. Norton and barges	....		....	....	1,350	1,350
	9	Sidney Dillon and barges	86,861	49,305	....	3,910	....	3,910
	9	My Choice and barges	90,499	....	....	2,534	....	2,535
	10	E. M. Norton and barges	78,790	....	....	2,206	714	2,920
	13	Port Eads and barges	134,701	....	....	3,740	....	3,740
	14	My Choice and barges	132,606	....	....	3,710	....	3,710
	14	Sidney Dillon and barges	150,365	....	....	4,210	....	4,210
	17	Henry Lourey and barges	158,812	....	....	4,445	1,160	5,605
	18	My Choice and barges	142,358	....	....	3,986	....	3,985
	21	....do	81,062	....	....	2,269	1,101	3,370
	25	Sidney Dillon and barges	53,964	....	....	1,510	540	2,050
	27	Jay Gould and barges	80,145	....	....	2,245	....	2,245
	28	My Choice and barges	83,420	....	....	2,335	....	2,335
	31	Sidney Dillon and barges	72,480	....	....	2,030	....	2,030
Feb.	1	Jay Gould and barges	57,552	....	....	1,610	1,705	3,315
	3	Sidney Dillon and barges	133,039	....	....	3,725	....	3,725
	6	Jay Gould and barges	98,617	....	....	2,711	1,104	3,815
	8	My Choice and barges	163,039	....	....	4,565	....	4,565
	11	Jay Gould and barges	115,200	....	....	3,225	....	3,225
	8	Sidney Dillon and barges	117,000	20,160	....	3,840	....	3,840
	12	....do	78,029	....	....	2,183	992	3,175
	15	E. M. Norton and barges	155,750	....	....	4,360	....	4,360
	17	My Choice and barges	107,000	....	....	2,995	935	3,930
	19	Sidney Dillon and barges	146,318	....	....	4,095	....	4,095
	21	My Choice and barges	134,420	....	....	3,765	....	3,765
	22	E. M. Norton and barges	104,000	....	....	2,910	....	2,910
	23	Oakland and barges	43,068	....	....	1,205	1,085	2,[illegible]

Shipment of bulk grain by barges to New Orleans during 1890—Continued.

Date.	Name of towboat.	Corn.	Wheat.	Oats.	Bulk grain.	Other freight.	Total.
		Bush.	*Bush.*	*Bush.*	*Tons.*	*Tons.*	*Tons.*
Feb. 24	Sidney Dillon and barges	105,000			2,940		2,940
27	...do	72,300			2,025		2,025
27	E. M. Norton and barges	101,576			2,845		2,845
28	My Choice and barges	83,000			2,323	1,112	3,435
Mar. 10	E. M. Norton and barges	74,750			2,095		2,095
11	Sidney Dillon and barges	68,455			1,916		1,916
12	My Choice and barges	86,200			2,415	1,095	3,510
14	Sidney Dillon and barges	153,700			4,305		4,305
15	Jay Gould and barges	153,700			4,305		4,305
15	H. M. Hoxie and barges	103,000			2,886	1,164	4,050
17	My Choice and barges	145,000			4,075		4,075
17	Sidney Dillon and barges	155,010			4,340		4,340
19	Jay Gould and barges	115,900	15,160		3,695	1,255	4,950
20	My Choice and barges	157,851			4,420		4,420
21	Sidney Dillon and barges	100,000			2,800		2,800
23	My Choice and barges	72,999	20,289		2,650	2,060	4,710
27	Sidney Dillon and barges	99,053			2,770		2,770
29	My Choice and barges	105,000			2,940	1,185	4,125
Apr. 1	Sidney Dillon and barges	156,243			4,375		4,375
2	My Choice and barges	134,000			3,752	1,123	4,875
5	Sidney Dillon and barges		39,463		1,183	1,092	2,275
5	Jno. Gilmore and barges	152,000			4,255		4,255
8	My Choice and barges		80,391		2,410		2,410
8	Sidney Dillon and barges	47,500			1,330	900	2,230
11	Henry Lourey and barges		148,210		4,445		4,445
12	My Choice and barges	86,044	47,189		3,820		3,820
16	Future City and barges		18,978		571	1,659	2,230
23	Sidney Dillon and barges	10,000			280	1,905	2,185
23	Woods and barges	45,513	92,402		4,050		4,050
27	Sidney Dillon and barges	50,000	45,360		2,760		2,760
28	Jno. Gilmore and barges	86,425			2,420	1,530	3,950
30	Sidney Dillon and barges	128,714			3,605		3,605
30	Oakland and barges	90,454	42,830		3,810	1,400	5,210
May 3	Sidney Dillon and barges	50,081			1,403	2,742	4,145
7	Henry Lourey and barges	137,149	19,880		4,440		4,440
11	Sidney Dillon and barges	90,869			2,745		2,745
12	Jay Gould and barges					3,115	3,115
17	Sidney Dillon and barges	96,356			2,695		2,695
18	Henry Lourey and barges	96,998	16,000		3,195	2,840	6,035
20	Sidney Dillon and barges	148,000			4,145		4,145
22	H. M. Hoxie and barge	48,360			1,355	2,340	3,695
27	Sidney Dillon and barges	151,621			4,245		4,245
28	Oakland and barges	88,713			2,490	2,375	4,865
30	Sidney Dillon and barges	147,474			4,130		4,130
31	My Choice and barges	74,010			2,074	1,726	3,800
June 7	Jno. Gilmore and barges	83,143		39,960	2,885		2,885
7	My Choice and barges	96,500			2,701	1,689	4,390
14	...do	50,000			1,400	2,230	3,630
21	...do	116,350			3,260	1,565	4,825
28	H. M. Hoxie and barges	130,000			3,640	1,215	4,855
July 6	Oakland and barges	200,002			5,600	1,080	6,680
12	Future City and barges	56,000	100,000		4,570		4,570
12	Sidney Dillon and barges	79,000			2,210	1,630	3,840
17	Jno. Gilmore and barges	82,000	35,000		3,346	1,194	4,540
23	Sidney Dillon and barges	100,000	20,000		3,400		3,400
28	Henry Lourey and barges	73,000			2,045	1,200	3,245
26	Jay Gould and barges	48,000	62,263		3,210	2,005	5,215
Aug. 2	Sidney Dillon and barges		60,000		1,800		1,800
2	H. M. Hoxie and barges					1,610	1,610
9	Sidney Dillon and barges		11,356		340	1,935	2,275
16	...do					2,085	2,085
21	...do	58,500			1,640		1,640
23	...do	44,000			1,230		1,230
23	My Choice and barges					2,245	2,245
28	Sidney Dillon and barges	60,000			1,680		1,680
29	My Choice and barges	40,000			1,120	620	1,740
30	Sidney Dillon and barges	18,100			505	1,160	1,665
Sept. 3	...do	65,000			1,820		1,820
3	Jay Gould and barges	63,086			1,770		1,770
4	My Choice and barges	59,437			1,665		1,665
8	...do	20,000			560	1,340	1,900
12	Jay Gould and barges	60,000			1,680		1,680
13	My Choice and barges					1,440	1,440
20	...do	47,000			1,316	1,764	3,080
20	Jay Gould and barges	64,889			1,800		1,800
27	...do					1,170	1,170
Oct. 4	...do					1,210	1,210
11	...do					1,250	1,250
18	...do	15,000			420	650	1,070
25	Sidney Dillon and barges		86,195		1,085	1,130	2,215

Shipment of bulk grain by barges to New Orleans during 1890—Continued.

Date.	Name of towboat.	Corn.	Wheat.	Oats.	Bulk grain.	Other freight.	Total.
		Bush.	*Bush.*	*Bush.*	*Tons.*	*Tons.*	*Tons.*
Nov. 1	Sidney Dillon and barges	25,000		50,000	1,500	875	2,375
8	...do		71,709		2,150	850	3,000
15	...do		50,000		1,500		1,500
17	Jay Gould and barges					980	980
20	Sidney Dillon and barges		50,000		1,500		1,500
22	Jay Gould and barges		50,000		1,500	925	2,425
27	...do		75,000		2,250		2,250
Dec. 1	...do	15,518			335	915	1,250
3	Sidney Dillon and barges		57,512		1,710		1,710
4	Jay Gould and barges		42,488		1,290		1,290
6	Sidney Dillon and barges					1,040	1,040
12	Sidney Dillon, My Choice, and barges	16,050			450	2,060	2,510
	Total	8,717,849	1,409,440	89,960	287,630	84,366	371,996

APPENDIX D.

REPORT OF CAPTAIN S. W. ROESSLER, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FIRST AND SECOND DISTRICTS.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 25, 1891.

GENERAL: I have the honor to submit the following report of operations in the first and second districts for the period May 31, 1890, to May 31, 1891.

The first district extends from the mouth of the Ohio River to the foot of Island No. 40, embracing 220 miles of river. The second district extends from the foot of Island No. 40 to the mouth of White River, a distance of 173 miles. Works of improvement have been executed at various points and will be noted in order, beginning at the upper end of the districts.

The districts were in charge of Capt. Smith S. Leach, Corps of Engineers, to June 19, 1890, and have been in my charge since.

COLUMBUS, KENTUCKY.

The act of August 5, 1886, appropriated $18,750, and the act of August 11, 1888, $25,000, for work at this point. The object for which the appropriations were made was to protect the town of Columbus from threatening danger of destruction on account of rapid caving of the bank in its front.

The project prepared by the district officer for this purpose and as approved by the Commission and the Secretary of War, provided for the construction of five crib dikes of brush and stone so spaced apart as to protect about 2,200 feet bank where the caving was most threatening. Each dike consisted of (1) a foot mat 200 feet long up and down stream and extending from the zero contour 300 feet out into the river and (2) a single brush crib, 28 feet wide and 8 feet high, placed with its center line 12 feet upstream of the center line of the foot mat, and extending from the upper edge of the mattress to a point 240 feet beyond the low-water contour.

During the working season of 1889-'90, Dikes Nos. 4 and 5 were completed, and the foot mat of Dike No. 3 and shore half of the foot mat of Dike No. 2 were laid.

Preparations for completing the work were commenced in August, 1890. Proposals for brush and poles were opened August 7, Bryant & Pickett, of Hickman, Ky., receiving the contract at $1.05 per cord for brush and $1.50 per cord for poles. The first tow of plant left Plum Point August 30, and the last tow was delivered at Columbus, September 14, considerable delay being caused by the bursting of flues in the boilers of the steamer *Titan* on three separate occasions. Grading was commenced September 6, at the site of Dike No. 1. The construction of the mat for Dike No. 1 was commenced September 19, and by October 20 the dikes were completed as projected, excepting the crib of Dike No. 3, which was omitted on account of lack of funds. The location of the work and the details and dimensions of the dikes are graphically represented on the accompanying sketch.*

* Not printed.

The conditions were not favorable for doing the work economically. Fair progress only was made on account of delays incident to rainy weather, high water, and drift. Under more favorable circumstances there would have been a sufficient amount of money left to build the crib of Dike No. 3 also, but the omission of this crib does not impair the efficiency of the system. On the contrary, it is in one sense an advantage, as, from the proposed location, it would have formed an obstruction to boats approaching the regular landing.

An itemized statement of expenditures is herewith, as well as the usual fiscal statement.

HICKMAN, KENTUCKY.

The improvement at this point consists of 1,000 feet of continuous revetment of brush and stone, extending from the lower side of the indurated clay point which projects into the river to a point near the old railroad depot. This revetment was built in the fall of 1889, and is fully described in last year's annual report. No work has been done during the current fiscal year. The stone which had been purchased for the extension of this revetment and stored on the bank above the town has been used in the Osceola bar revetment to avoid transferring it back farther from the river, which would have been necessary on account of rapid caving of the bank. An inspection of the revetment, made by William M. Rees, assistant engineer, when the river had fallen to about two-thirds stage, shows that the shore mattress had sustained no injury excepting at the lower end, where it had been slightly undermined by eddy action.

At the close of the last fiscal year there remained a balance of $48,647.78 to the credit of this work. To this has been added $500 by allotment from the river and harbor act, approved September 19, 1890. It is proposed to make a survey of the locality during the coming low-water season to determine how the funds can be applied to the best advantage.

NEW MADRID REACH.

An allotment of $1,000 was made out of the river and harbor act approved September 19, 1890, for the purpose of making a survey of this reach with special reference to the caving in progress in the vicinity of New Madrid. This survey will be made during the coming low-water season.

PLUM POINT REACH.

The portion of river included under this head, as designated by the Commission, extends from the head of Island No. 26, 147 miles below Cairo, to the head of Island No. 35, a distance of 40 miles. The improvements which have been made under this title up to the present time extend over a distance of 20 miles of river, beginning at a point 1 mile above Daniel Point and ending near Craighead Point.

At the beginning of the fiscal year there were no funds available for continuing the improvement in this reach, excepting a small balance for the completion of the dikes in Elmot Chute and the chute of Island No. 30.

An allotment of $297,500 became available out of the river and harbor appropriation approved September 19, 1890, which was subsequently reduced to $172,500 by the withdrawal of $125,000 for use in high-water protection of levees. The amount so withdrawn was restored out of the appropriation approved March 3, 1891, and an additional allotment of $322,500 was made, making a total of $622,500 available for continuing the improvement, which, according to the expressed wish of the Commission, was to be applied to the following objects, and in amounts approximately as stated:

Daniel Point revetment, extension of, upstream	$22,000
Ashport Bend revetment	366,500
Fletcher Bend revetment, completion of	75,000
Osceola Bar revetment	119,000
Repair of dikes in chutes of Elmot towhead, and of Island No. 30, or construction of a dam in Gold Dust Chute	40,000
	622,500

In addition, an allotment of $130,500 became available out of the appropriation act approved September 19, 1890, for the repair and reconstruction of the consolidated plant belonging to the first and second districts.

REVETMENT AT LOWER END OF OSCEOLA BAR.

At the time the first allotment became available the revetment of the lower end of the bar had become the most urgent work in the reach. The rapid caving then in

progress, and which had been very active since the flood of 1890, threatened to carry away the entire lower end of the bar and to reopen Bullerton Chute, the dikes of which, having become weakened by age, were in no condition to stand a heavy strain; an event, had it occurred, which would have destroyed at one blow all the good results obtained from the Osceola Bullerton system of dikes built in the early history of the Plum Point improvement. Therefore all the work which it was possible to do in this reach in the few months remaining before the beginning of the high water season was done at this point.

The project for the protection of this bank as submitted by the district officer and as finally approved by the Commission and the Secretary of War, provided for a continuous revetment of brush and stone mattress, beginning at the head of Bullerton towhead and extending 7,000 feet upstream, terminating at the upper limit of caving.

On my return to Memphis after the October meeting in New York, I immediately commenced preparations for executing the work, but there being no reserve stone supply in the reach that could be drawn on, the date of beginning active field work was deferred until there was enough stone in sight to sink the first mattress after it should be completed. Grading with the hydraulic jet was commenced November 8 with one pile driver, and on the 11th hydraulic grader No. 2 was put in commission.

The construction of the first mattress, 1,100 feet long, was commenced on November 14 and completed December 2, but owing to nonarrival of stone was not sunk till December 4. The second mat, 1,200 feet long, was commenced December 8 and completed and sunk on the 19th. A second revetment party, having completed the repairs to the Hopefield Bend revetment, commenced the construction of the third mat, 1,100 feet long, on the 23d, and as soon as 500 feet of mat had been built the fourth mat was commenced by the first party on the 30th. Mat No. 3 was sunk on January 5, and mat No. 4 on January 13.

In details of construction the mat work was the same as that used at Daniels Point, the shore extension being built simultaneously with and woven into the river mat before sinking. At parts of mats Nos. 3 and 4 this method could not be followed on account of the low banks, which were almost submerged by the rapidly rising river. Here connecting mats were resorted to, which were sunk February 3, after being afloat some days on account of nonarrival of stone.

In addition to the regular bank protection, 4 brush and stone cribs were constructed to close small chutes: One between head of Bullerton Towhead and small towhead, 100 feet long, 20 feet wide, and 11 feet high; one between head of Bullerton Towhead and foot of Osceola Bar, 312 feet long, 35 feet wide, and 5 feet high; one opposite Mat No. 3, 100 feet long, 40 feet wide, and 4 feet high; and one 100 feet long, 32 feet wide, and 3 feet high, near the upper end of the bank revetted. The cribs were all placed on foundation mattresses of sufficient width to prevent undermining by scour. The small towhead at the head of Bullerton Towhead was revetted at the upstream salient, where it was exposed to the full force of the current.

From the very beginning of the work exceptional difficulties were encountered, caused principally by high water and drift. The latter was very troublesome and it would have been impossible to construct and sink with safety any one of the four river mattresses built during the season without the aid of a drift boom, located above the mooring barges, to arrest and deflect the mass of the drift and prevent its lodgment at the head of the mat. The most difficult experience occurred during the rise which culminated November 23. On this date the river was fairly covered with drift, and in order to save the first boom and the mat already constructed, it was found necessary to throw out a second boom some distance above the first one. On this occasion the entire force was occupied two days in fighting drift.

Mr. Nolty, assistant engineer, was in immediate charge of this work and it is to his credit that no mattresses were lost under the great difficulties with which he had to contend. His report is hereto appended.

The following is the result of the season's work at this point:

Length of bank protected	feet..	4,500
Number of subaqueous mattresses		4
Dimensions of subaqueous mattresses Nos. 1, 3, and 4	feet..	1,100 by 200
Dimensions of subaqueous mattress No. 2	do...	1,200 by 200
Dimensions of shore mattresses (average)	do...	4,500 by 60
Crib work	cubic yards..	3,933
Foundation mats for cribs (estimated)	square yards..	3,000

The total expenditure to date on account of this work is $68,389.67, or $15.15 per linear foot. This does not include any charge for office expenses which have not at this writing been distributed among the different allotments. Considering the difficulties of the work, the cost compares very favorably with that of similar work done in former seasons.

Three-fifths of the stone used was supplied by the general service, the quarry price being 65 cents per cubic yard. The remainder was obtained from the supply at Hickman, and by open market purchase, at $1.65 per cubic yard, delivered on barges at the work.

The brush and poles were obtained by an open-market purchase, the work not permitting the delay of an advertisement. The prices paid were $1.02 per cord for brush and $1.65 per cord for poles.

An inspection of the revetment since the late flood shows it to be in perfect condition. When active field operations were discontinued in February it was feared that a part of the upper end might be lost during the flood, as the current seemed to set in strongest at that point. Happily, these fears have not been realized, due to the fact that the middle ground between Osceola Bar and Plum Point has extended itself downstream several hundred yards, causing the current to exert its maximum attack at a point lower down on the revetment. In view of this change in the position of the channel crossing, it is probable that a lesser length of revetment than originally contemplated will suffice to check all the caving at this point. From present indications I am of the opinion that the upper 1,000 feet of the proposed revetment can be safely omitted.

The usual exhibit, giving the expenditures for stone, brush, labor, etc., is submitted herewith.

DIKES IN ELMOT AND ISLAND NO. 30 CHUTES.

The last annual report of the district officer reported these dikes within a few days of completion. Elmot Chute Dike was completed June 12, 1890. In Island 30 Chute, the last 220 feet of the dike, where it crosses the deepest water, had not been entirely finished when the incomplete work was broken through by the pressure of drift on June 2. The depths ranging from 16 feet below zero at the upstream row of piles to 57 feet below at the downstream row, the continuation of the dike on the old line was deemed impracticable and a new line was selected, in the form of a redan, with the apex about 75 feet upstream of the front row of piles of the standing dike. This location brought the new structure into comparatively shoal water. As the original foot mattress extended 75 feet above the dike, no new mattresses were thought necessary. The work of closing this gap was commenced July 7 and completed July 25. The new work was built on the original design but was given greater strength by the insertion of a second set of horizontal braces placed on the level of mid stage.

Elmot Chute Dike remained intact until November 24, on which date the drift broke through where the structure crossed the deepest water, or about 400 feet from Elmot Bar shore. It is noted that this event occurred the day following that on which so much difficulty was experienced in saving Mat No. 1, at Osceola Bar, from destruction by the large quantity of drift which came down on that day. The gap thus made was about 125 feet wide, and the adjacent portions of the standing dike, especially that next to Elmot Bar, were badly broken up. Owing to the unfavorable conditions of high water and presence of floating drift, the work of closing the gap was not commenced till December 16. The depths being too great to continue the dike on the original line, the new work was given the form of a redan so as to bring the structure on moderately shoal ground. An additional set of horizontal braces was inserted at the level of mid stage, and the adjacent portions of the standing dike were strengthened in the same way. Progress was slow, being greatly retarded by rising river, rapid current, and floating drift, and the work was not completed till February 5.

The completed dike in chute of Island 30 remained intact until February 3, 1891, on which date the accumulated drift again broke through, destroying nearly the whole of the new work built in July, 1890, and leaving a gap about 250 feet wide, with the ends of the standing dike badly broken up. After this second failure I entertained serious doubts as to the ability of any pile dike of ordinary strength to resist the pressure of the drift that was likely to accumulate against it, and no steps were taken to close the gap. The strong current which was maintained through the gap during the remainder of the flood has caused a deep excavation within and below the gap. Considerable caving also has taken place along the bank below the gap, resulting in the destruction of about 2,000 feet of the Plum Point Levee.

On February 16 a second break occurred in Elmot Dike adjacent to Island No. 30 shore, where a high deposit had previously been formed and no danger anticipated. Two hundred feet of dike was carried away at this point, together with bank revetment above and below the dike. After the destruction of the revetment the bank caved in rapidly, enlarging the opening to a width of 300 feet before the subsidence of the flood. On March 10 a third gap occurred in Elmot Dike, which widened to 3[illegible] feet before the end of the flood. This break also occurred at a point where a high deposit existed above and below the dike.

After the destruction of the new repair work in the dike of Island 30, no further

attempts were made to maintain the dikes during the remaining period of the flood, and subsequent events proved this to have been the best course to follow.

The accompanying sketch* of a survey made April 3–15, 1891, shows the locations and dimensions of the existing gap, and the scour produced in the bed and banks. A comparison of this map with previous surveys indicating that the effect of the dikes as a whole has been beneficial in producing a deposit of some extent in channels above them, as far as the Gold Dust system of dikes.

I have closely examined both dikes since the flood, and I am of the opinion that it will not be expedient or economical to endeavor to close the chutes by repairing the old dikes, even if another attempt at closure should be made with some form of pile dike. There are no suitable sites for the new structures which would be required to close the existing gaps, and the completed dike would still be a weak and uncertain one, however strong the new portions might be made.

Taking the above facts in connection with the experience gained in Bullerton Chute, the conclusion is evident to my mind that pile dike structures are not suitable to close channels of considerable dimensions, such as the two under consideration, where drift is liable to accumulate in large masses. They have proved very efficient in contracting a channel to smaller widths, and on sites where the tendency to deposit already existed, and where the flow of drift was a minimum, also, in closing small side channels where but little drift was liable to run. But as structures for closing large chutes they have never possessed the requisite strength to resist drift, and to this extent have been unsuccessful.

In compliance with a resolution of the Commission passed at the March meeting, a project is being prepared for arresting the flow through both chutes by closing their common tributary, Gold Dust Chute, in the vicinity of range 19, shown on the accompanying sketch.* In designing the new dike, the central idea will be the use of a solid dam of brush and stone, similar to that used in improving Alton Harbor about 1881.

An allotment of $40,000 made at the March meeting of the Commission stands to the credit of this work.

DANIELS POINT REVETMENT.

The improvement at this point consists of a continuous revetment of brush and stone, beginning at the extreme lower end of a long caving bend and extending 5,300 feet upstream. It is fully described in the last annual report of the district officer.

After the subsidence of the flood of 1890 it was found that the extreme upper end of the revetment had been slightly undermined by caving in the bank, and that at a point several hundred feet below the upper end the bank seemed to have washed out from underneath the revetment, causing the latter to settle several feet below grade, but producing no rupture in the mattress. An inspection of the work since the flood of 1891 shows a rupture in the revetment where the settling had occurred last year, but no additional injury is noted at the extreme upper end of the revetment, where the caving in the unprotected bank seems to have ceased for a distance of several hundred feet. With these exceptions the revetment remains in perfect condition.

The proposed work for the current year is an extension of the revetment a distance of 500 or 600 feet upstream, so as to secure the present head of the revetment which on account of the caving of the unprotected bank has assumed a salient position with respect to the bank above. It is proposed to expend about $12,000 on this extension and in repairing the rupture in the mattress above noted. The balance of the $22,000 allotted for this point it is proposed to hold in reserve for possible use another season, to extend the work of this season should it in time become endangered by the caving of the bank above it.

ASHPORT BEND.

The caving in this bend, though never very rapid, has been active throughout the year. A comparison of the surveys of October, 1890, and May, 1891, of which traci are furnished herewith,* shows that during this interval the caving extended ov distance of 15,400 feet, beginning at a point about 4,400 feet below Ashport Li and ending at Gold Dust. The most active caving has taken place in the vicin of range 23 and range 26+900, being 300 feet at the former and 200 feet at the lat

The shape which the bend now has is a suitable one to hold as a permanent ba line, and for this reason the Commission has made allotments aggregating $366, to revet the entire bank between Ashport and Gold Dust, or so much of it as may necessary. It is expected to complete this work, or nearly so, during the comi season, if the conditions, mainly of weather and stage of river, prove favorable.

*Not printed.

FLETCHER BEND REVETMENT.

The revetments in place at the time of the last annual report are known as sections A, B, C, D, and E. Section A is a continuous revetment 7,800 feet long, and protects the upper end of the bend. Sections B, C, D, and E protect the lower end of the bend, and taken together constitute the experimental interrupted system of revetment authorized by the Commission with the view of ascertaining whether short intervals of unprotected bank might not safely be left between blocks of continuous revetment, thus decreasing the cost of a given length of protection. The interval between sections B and C is 300 feet; C and D, 400 feet; D and E, 500 feet. As was to be expected, some caving has taken place in the unprotected intervals, but not to any serious extent. The lower end of section E has been undermined, and it is probable that an extension of this block a short distance downstream may be necessary. While the interrupted system has safely stood the effects of two floods, it has at no time been subjected to a strong attack of the current, and, therefore, no conclusion can safely be drawn as to its efficiency in very exposed situations. Section A remains uninjured.

The reballasting of the shore mats of sections B, C, D, and E is in progress at present writing. This work was authorized by resolution of the Commission, and will be paid for out of the allotment for care and preservation of existing works.

The work authorized for the current year, and for which an allotment of $75,000 is available, is the revetment of the unprotected interval, 3,800 feet long, between sections A and B. The stone required at this point is nearly all delivered and stored on the bank at section A, and the brush and poles have been advertised for.

CONDITION OF WORKS IN THE REACH NOT ALLUDED TO IN THE FOREGOING PAGES.

The condition of the Gold Dust and Yankee Bar systems of dikes remains substantially the same as at the date of the last annual report. No new injuries that are noticeable have taken place during the year.

The remnant of the old Osceola Bullerton Dike at foot of Osceola Bar was removed in August, 1890, by the U. S. snag boat *H. G. Wright*, it having become a serious obstacle to navigation by the caving away of the bank behind it. With this exception, the Osceola system of dikes remains unchanged.

Bullerton Cross Dike, No. 2, which maintains the closure of Bullerton Chute, has received no new injury during the year. The revetment of Bullerton Towhead and the piece of revetment near the center of Osceola Bar remain unchanged; neither has been subjected to any strain. The injury to the lower end of the Plum Point revetment has been increased to a slight extent by the caving in progress in the unprotected bank, but the added damage is not sufficient in amount to give any apprehension as to the safety of this work, especially in view of the fact that the maximum attack of the current has been transferred from the revetment to a point on the bank some distance below.

SURVEYS AND OBSERVATIONS.

Two complete hydrographic surveys of the reach have been made during the year, one in October, 1890, the other in May, 1891.

Tracings of these surveys are herewith.* The routine weekly observations for depths and velocities at the shoal crossings have been continued, except during the times when the survey party was employed elsewhere.* The results of these observations are given in a table accompanying this report. It will be noted that Gold Dust Crossing has been added to the list of shoal places heretofore included in the weekly examinations.

CHANGES IN THE BED OF THE RIVER.

A comparison of the survey of October, 1890, with that of May, 1891, shows that ortant changes in location and positions of the channel have taken place during late flood. The changes in the positions of the crossings may be inferred from positions of the Government lights before and after the flood. Ashport Light has n moved downstream 900 feet; Fletcher Light, 300 feet; New Haven Light, 600 ; Plum Point Light, 1,000 feet; Osceola Bar Light, 2,300 feet; Yankee Bar ight, 1,900 feet; Pettys Light, 1,400 feet. Gold Dust Crossing, while it has not materi- r changed its position, is not as clearly defined as the others in the reach. This s the main trouble with this crossing last year, and will probably be again this r. This was also the shoalest crossing in the reach at the time of the last routine rvations taken on May 25, 1891, the least channel depth being 13 feet at 7.7-foot

* Not printed.

stage. From Fletcher Light to the foot of the unprotected bank in this bend the channel follows closely the Arkansas shore. But from the latter point to a point near the middle of the Island 30 Crossing there now exists 2 channels, a new one more or less distinct having developed on the Elmot Bar side of the river. The main channel, as heretofore, continues down the Arkansas shore to New Haven Light, but from the shape which the unprotected piece of bank referred to has taken, which is favorable towards the maintenance and development of the auxiliary channel, a radical change in the location of the thalweg in this vicinity may be anticipated. Plum Point, Osceola Crossing, has moved about one-half mile downstream. Bullerton Channel has practically disappeared by the complete shoaling of the upper end, while Bullerton Gap at the foot of the towhead shows an enlargement. The bars and middle grounds show changes corresponding to the changes noted in the position of the channel. Considerable accretions have taken place at the foot of Island 30, and a corresponding amount of scour has taken place in the middle bar opposite. The tail of the latter has made downstream about 2,500 feet. The bar between the former Bullerton Channel and the main channel has been very considerably diminished in height and width, and there has been a corresponding approach of the main channel to the Bullerton shore. The survey of May, 1891, was made at a medium stage and on a falling river before the latter had begun to adjust itself to low-water conditions, but I think its indications may be accepted as showing a decided tendency in the channel to resume its former course close to and parallel to Bullerton shore, and to cross to the mainland by what is now known as Bullerton Gap.

MEMPHIS HARBOR.

During the low-water season of 1890, the sum of $4,802.33 was expended in dredging a channel through the bar to the elevator.

Work was commenced August 23 and continued through September and a part of October. The dredge, which was a modified form of the clam-shell type, did not prove suitable for the work, but was the best one available at the time. The material excavated was very tenacious and the weight of the digger was insufficient to cause it to settle far enough down to bring up a full load. The work was done as an open market transaction, at a price of $85 per day for 10 hours' work. As the river did not reach a very low stage during the season, the progress, though slow, proved sufficient to prevent any interruption in the steamboat traffic to the elevator.

Upon completion of the work at Columbus, Ky., the revetment plant there used was transferred to Hopefield Bend, to repair a piece of revetment of 1887, 762 feet long, which had been destroyed during the flood of 1890. Grading was commenced October 13 with second district grader No. 40, and completed November 18, one pile driver assisting with one jet when not otherwise engaged. The mattress plant was put in position November 13, and weaving commenced the same day. The subaqueous mat and part of the shore mat were completed December 2 and sunk December 4. The shore mat was completed and ballasted December 14. The heavy run of drift in the latter part of November, and which has been previously referred to in connection with the Osceola Bar revetment, gave considerable trouble at this point on November 24, after 500 feet of mat had been completed. The presence of a coal fleet several hundred yards above protected the shore end of the mooring plant, but the drift accumulated in large masses at the outer end of the outer mooring barge. This was subsequently dislodged by letting go the slip lines of the mat head and hauling the shore end of the barge upstream. The operation was attended with considerable difficulty and great risk, but was successfully carried out without any injury to or loss of mat. The method of building the mat was the same as that used at Osceola Bar, the river mat being woven into the shore extension before sinking. The mat varied from 290 to 360 feet in width and terminated at about three-fourth stage. In its construction there were used 1,865 cords of brush, 242 cords of poles, and 1,527 cubic yards of stone. The total cost of the field work was $13,735.76.

HOPEFIELD BEND REVETMENT.

A recent examination shows the following breaks to have occurred during the flo of 1891. They are noted in order, beginning with the one farthest upstream.

1. A break 250 feet long in the shore mattress of the 1885 work, extending from t low-water line to the top of the bank. Some of the revetment on the top of the ba still remains in place. The repairs required are regrading, paving, and a foot m The subaqueous mattresses of the 1885 work were 150 feet wide, but in sinking w held well out beyond the zero contour by piling along the inner edge of mat. Thi the first point where the current strikes the revetment with sufficient force to ca scour. Above this, towards Mound City, the shore mats are decayed and ragged, ' are protected against injury by the sand bar opposite Mound City.

2. From the lower end of the 1885 work there was a piece of revetment 1,600 feet long placed in 1884. The shore mattress of this work has all disappeared. Soundings taken with a wood pole shod with a steel point disclosed the fact that the subaqueous mattress was still there, being found at a distance of from 50 to 80 feet from the water line at an 11¼-foot stage. This can be repaired by regrading and paving and a subaqueous mat about 100 feet wide.

3. The 1887 work begins at the foot of the 1884 work just described, and for a distance of 1,000 feet below the upper end the shore mat is badly broken up. In two places pockets have caved back to the top of the grade. The subaqueous mattress remains uninjured, the shore edge being found close to the water line. The repairs required are regrading, paving, and a foot mat.

4. Farther down on the 1887 work, and just above the repair work of 1890, there are two more breaks in the shore work, the upper one 550 and the lower one 150 feet in length. They can be repaired by regrading, paving, and foot mats.

Below the repair of 1890 to Hopefield Point the revetment remains practically uninjured, but there is a deficiency of ballast on the shore mat.

The cost of the above repairs is estimated at about $91,000. A special report has been submitted to the president of the Commission, with recommendation that the repairs be made this year, and that the funds therefor be taken, if necessary, from the allotment for Plum Point Reach.

SAND BAR AT UPPER END OF HARBOR.

On June 4, I received telegraphic notice from the president of the Commission that the sum of $15,000 or so much thereof as might be necessary could be used from the allotments for Plum Point in dredging a low-water channel to the elevator. Inquiries were at once made for a suitable dredge plant and letters addressed to all parties in the valley who were likely to know of such plant, to one party in Pittsburg, and to a large dredging firm on the Gulf coast. At present writing no replies have been received and no progress made towards commencing the work. The only dredge now in view that may prove suitable is a suction dredge with an 8-inch discharge pipe now being constructed at Memphis and to be completed in about 2 weeks. The channel to be dredged is about 1,400 feet long, and allowing a bottom width of 100 feet, side slopes of 1 on 4, and a depth of 10 feet below zero stage, the amount of material to be moved will approximate 7,500 cubic yards. Should the river not reach the zero stage a less amount of dredging will suffice.

I recently made a special examination of this portion of the harbor, as required by the river and harbor act approved September 19, 1890, and forwarded my report to the Chief of Engineers through Gen. C. B. Comstock, as Division Engineer*. For the sake of completeness in this annual statement I quote in full the report referred to.

"The project for the improvement of Memphis Harbor and Memphis Reach, as submitted by Captain (now Major) Miller in 1882, and as approved by the Commission, contemplated the revetment of Hopefield Bend from Mound City down, as the rapid caving then in progress, by changing the position and direction of the current, threatened injurious changes in the bed of the river in front of Memphis. The position of Hopefield Point and the shape of the bend above it were at that time favorable to the maintenance of the deep-water channel along Memphis front, by causing the main current to set in to the Tennessee shore at the extreme upper end of the harbor front in the vicinity of the mouth of Wolf River. In fact so vigorous was the attack of the current at this point that the same project contemplated repairing and strengthening the revetment already in place in the vicinity of the mouth of Wolf River and an extension of the revetment upstream to the mouth of Frames Chute. The protection work in Hopefield Bend was commenced in 1882, and beginning at Mound City was extended downstream as rapidly as funds were provided, being finally completed by the extension of the revetment to Hopefield Point in 1888. The long period occupied in the execution of the work was due to the absence of the necessary funds at the proper time, and Hopefield Point, which was the key to the whole situation, was not reached till it had caved back about 3,000 feet from the posi- ti[illegible] in which it should have been held. The bank line as finally protected presents a [illegible]early straight course along the lower end, and the main current of the river, follo[illegible]ing closely the same general direction, has transferred its point of maximum at[illegible]ck from the vicinity of the mouth of Wolf River to the lower end of the paved le[illegible]e near the foot of Beale street. During the progress of this change in the positi[illegible] and direction of the main river current, an eddy action grew up along the upper p[illegible]ion of the harbor, causing the deposit which is the subject of this report.

[illegible]he accompanying sketch of a survey made April 21–25, 1890, shows the present di[illegible]ensions of this bar, the numbers inclosed in small circles indicating height of

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[illegible]'or action of the Division Engineer and of the Chief of Engineers on this report se[illegible] page 257, Part I.

deposit above the plane of zero or low-water stage. Comparing this sketch with a survey made in July, 1890, I find that the tail of the bar has been extended about 500 feet farther downstream, and that considerable accretions of deposit have been received on the channel side of the bar, the maximum expansion being about 600 feet opposite Hopefield Point. No further expansion is, however, likely to occur, as the zero contour is now but little over 2,000 feet from the Arkansas shore. No material change in the height of the bar is noted.

Taking into consideration the present position of the zero contour, its uniform curvature and general parallelism to the zero contour of the opposite bank, and the form of the protected bank above Hopefield Point, I think the conclusion is evident that the present forces are seeking to establish a new bank line approximately along the same contour, and that the only way in which this tendency can be overcome and a scour effected which will ultimately remove the bar will be by means of deflecting dikes at Hopefield Point.

All the facts in reference to this evil, excepting the result of the last survey, have been presented to and taken under consideration by the Mississippi River Commission. In a special report, dated December 10, 1889, to the president of the Commission, Captain Leach set forth at length the impairment of the harbor facilities of Memphis by the growth of this bar, and presented a project which was designed to ameliorate the evil rather than to cure it. The main features of his project were—

1. To build a training wall or dike 1,500 feet long from the present Mississippi bank immediately above the mouth of Wolf River, along a suitable curve so as to turn the discharge of Wolf River downstream along the shore.

2. To increase, if necessary, the natural discharge of Wolf River by clearing the banks of its tributary, the Loosa Hatchie, of brush wood and timber, and enlarging the section of Sycamore Bayou, which connects the Loosa Hatchie with the Mississippi above the head of Old Hen Island.

The conditions existing at that time were sufficient, in the judgment of Captain Leach, to justify the hope of success from this method of treatment, but the aggravated conditions, as they exist at the present time, seriously affect the prospect of even a moderate measure of success under this plan, unless accompanied by a very considerable and indeterminate amount of dredging over a distance of about 4,000 feet from Wolf River down to the lower end of the bar.

In my judgment the situation has narrowed down to the question whether it will be best to permit the formation of a new bank line, which in time would become available for the accommodation of shipping, or to attempt the removal of the entire bar by the construction of deflecting dikes at Hopefield Point. If the latter course, which I recommend for consideration, should be decided on, there is sufficient data on hand without further surveys to prepare a project. The locality is, in my opinion, worthy of improvement."

DIKES.

In the latter part of May, 1891, the foot of the bluff upon which the Walton Coal Company's incline rests settled about 5 feet, and a piece of the bluff about 200 feet long and 8 feet wide, opposite the interval between Dikes Nos. 2 and 3, settled vertically about 8 feet. No further caving has been noted in the vicinity of the dikes. The dikes themselves have sustained no injuries, as far as the surface indications show.

On August 31, 1890, some subaqueous blasting was done in the interval between Dikes Nos. 2 and 3, by private parties in the employ of the Walton Coal Company, the object being evidently to destroy a piece of projecting mat or crib which prevented access at low water to the foot of the incline. The matter being a very important one, I placed myself in consultation with the United States district attorney, and at the same time sent a full report of the facts to the president of the Commission. No action, however, was taken, as there appeared to be no law in existence at the time of the event, under which the guilty parties could be prosecuted. The river and harbor act approved September 19, 1890, furnishes a means for bringing before a United States district court all future acts of this kind.

BLUFFS BETWEEN DIKES AND BRIDGE.

A small amount of caving has taken place between the dikes and the revetm which has been placed by the bridge company to protect the east pier. This piec bank is 3,800 feet long and is the only part of Memphis front which is not protec from caving. Its protection is, in my opinion, important for two reasons, (1) preserve the current in its present perpendicular position to the bridge, and (2 prevent the destruction of valuable property on the bluff.

NONCONNAH ROCKS.

The examination ordered by the Commission has not been made, as the river not reach a low enough stage during the year to expose any portion of the rock

HELENA HARBOR.

The act of August 11, 1888, contained an appropriation of $75,000 for work at this point. The project, as submitted by the district officer and as approved by the Commission and the Secretary of War, provided for a protection covering 3,000 feet of bank, consisting of a continuous revetment of 600 feet from the upper side of the elevator down, and of five spur dikes, the first 1,100 and the fifth 2,875 feet from the same initial point.

Work was commenced August 26, 1889, and suspended January 17, 1890, on account of lack of funds. The following work remains to be done to complete the project on the original plan, and for which the Commission has made an allotment of $22,500 out of the river and harbor act approved September 19, 1890.

Dike No. 3. Paved embankment, 8,572 cubic feet of stone. One crib of 10,000 cubic feet.

Dike No. 4. Three cribs aggregating 110,000 cubic feet.

Dike No. 5. Foundation mat, 192 squares. Five cribs, 27,000 cubic feet. Paved embankment, 17,144 cubic feet of stone.

No injury to the work in place has been noted during the past year. There is no immediate urgency for the completion of the work, as the caving has ceased on the site of the revetment and for some distance below. In view of this fact it is my opinion that the money available for this point could be expended to better advantage to the interests of Helena, by applying it to the protection of Trotters Point opposite, the maintenance of which and of the bend above is necessary to the preservation of deep water along that part of Helena Front now used as a steamboat landing.

DELTA POINT, MISSISSIPPI.

Considerable apprehension has been felt regarding the safety of a piece of levee which at this point is in close proximity to a caving bank. The maintenance of this levee derives its special importance from the fact that there is no site farther back within a reasonable distance upon which a new levee could be built at moderate cost or without crossing very low ground. No accurate estimate has been made of the cost of such a levee in the event of the present one caving into the river, but from a rough approximation it is thought that the cost would be in the neighborhood of $100,000. As the dangerous caving only extends over a distance of about 1,400 feet, the cost of a suitable protection, at $20 per linear foot would be $28,000, or about one-third that of a new levee. This work is recommended, and I know of no point within the districts in my charge where money could be more advantageously expended in levee protection.

SURVEYS, GAUGES, AND OBSERVATIONS.

No low-water discharges were obtained for the season of 1890, as the river at no time reached what is called low-water stage.

After the November rise the fall in the river was quite rapid, and, in anticipation of a possible lower stage than had previously been reached, the regular survey party was sent to Helena and six observations taken at that point between December 23 and December 30. On the return of the party to Plum Point four sets of observations were taken on the Plum Point sections. As, however, the anticipation of a low stage was not realized, the observations possess no special value.

On February 18, the steamer *Abbot* with discharge party on board left for Columbus, Ky., for the purpose of taking the flood discharge at that point, arriving February 21. High winds prevented any observation till the 27th. Between this date and March 4, when the river came to a stand with 41.27 on the Belmont gauge, six sets of observations were taken, the meter method being used. The party then proceeded in advance of the flood wave and took one observation at Plum Point section March 5. The party then proceeded to Memphis where three observations were taken, the last one on the 10th, on which date the river came to a stand with 34.90 on t gauge. Observations at Helena were commenced by the same party on March 11 a l continued till April 13, twenty-six discharges being taken.

hortly after the first party left its station at Columbus, Ky., a second flood wave w reported from the Upper Ohio, and a second discharge party was organized for t t station, in anticipation of a higher stage than that at which the first observa- t ns were taken. Observations were commenced March 11, and continued till March 2 the method used being that of double floats. For the same reason a second d ble float party was organized to occupy the Fulton section, where six sets of o rvations were made.

l the field notes and field computations except those for the Plum Point sec- t s, have been forwarded to the secretary for the "official" computations, copies b retained for the use of this office.

In addition to the above, two observations for discharges were taken at the Robertsonville crevasse, but the results are unreliable on account of the existence of an eddy in the discharge section.

During the year six hydrographic surveys have been made, two at Plum Point, already referred to under the head of Plum Point Reach, and four at Memphis. The latter were limited in extent and covered only so much as was under special examination at the time. Of these, three were made with special reference to the bar formation at the upper end of the harbor, and one with reference to the faults in the Hopefield Bend revetment, caused by the flood of 1891.

The observations for velocity in a plane 5 feet below the surface, required by a resolution of the Commission under date December 4, 1888, have been resumed in Ashport Bend, and all the observations necessary to a study of the questions presented have been taken, except one observation at low water.

Gauge readings have been taken at all the stations without interruption during the year. The bulletin frame at New Madrid has been rebuilt, the old one being broken and decayed. The gauge posts at Fulton were destroyed on two occasions by drift, but were promptly replaced on each occasion by the regular survey party at Plum Point. A new bulletin and gauge posts have been placed at Mhoons Landing and at Sunflower.

SURVEY FOR LOCATION OF LEVEE ALONG ST. FRANCIS FRONT.

A survey for this object, from Point Pleasant, Missouri, to Council Bend, Arkansas, a distance of 200 miles, was made from October, 1888, to April, 1889, by a party in charge of Mr. S. E. Moore, assistant engineer. The office work of reducing the notes and preparing the profile was continued till December, 1889, after which it was suspended on account of lack of funds. An additional allotment of $300 having become available September 27, 1890, by transfer from the allotment for protection of levees, second district, the reductions were resumed and completed November, 1890. Two sets of profiles have been made, and the yardage has been checked by a second computation.

The upper end of the proposed levee rests on the high ground known as Big Prairie Ridge, which extends up to New Madrid and many miles north, forming a barrier to overflow at all points above in the St. Francis Basin, excepting at the extreme upper end, where a depression about 5 miles in width exists between the head of the ridge and the foot of Commerce Bluffs. In 1882 the estimated maximum escape over this depression was 88,000 cubic feet per second, and in 1883, 45,000 cubic feet per second. This escape reaches the St. Francis through Little River. The lower end of the proposed levee terminates on the high ground west of the west branch of Council Chute. Below this point a levee would be of no material benefit unless the St. Francis itself were leveed some distance above its mouth.

Between these points the line surveyed follows in general the high ground near the river, receding therefrom to what was considered a safe distance in caving bends. Where a rapidly caving bank approaches close to a lake the levee leaves the river and passes around the lake. Whenever favorable ground has existed across points it has been located there. Remnants of the old State and private levees have been utilized as far as practicable. The total length of the line selected is 177 miles. Adding to this the 23 miles of levee already built at Plum Point Reach, and which will form a part of the line, the total length of the proposed levee will be 200 miles. Geographically the line may be divided for convenience into three sections, namely:

Section No. 1, 66 miles long, from Point Pleasant to the upper end of the Plum Point levee.

Section No. 2, 56 miles long, from the foot of the Plum Point levee, near Craighead Point, to the high ground at Bradley Landing, in the bend of Island 40.

Section No. 3, 55 miles long, from Bradley Landing to Council Chute.

Much the largest part of the overflow into the St. Francis Basin takes place through section No. 1. During the flood of 1882 the outflow was estimated at 378,502 cubic feet and the inflow at 27,400 cubic feet per second, leaving a net escape of 351,102 cubic feet per second. During the same flood the estimated ‹ ‑ flow in section No. 2 was 20,362 cubic feet, and the inflow 15,805 cubic feet, leav g a net escape of 4,557 cubic feet. In section No. 3 the observations indicated n actual discharge from the St. Francis into the Mississippi, the net outflow be g estimated at 167,310 cubic feet, as against an inflow of 184,771 cubic feet per seco

At the time the survey was made and the reduction of the notes commenced, e engineer in charge contemplated giving the levee crown widths of 6, 8, or 10 f , depending on height of levee, side slopes of 1 on 3, and a grade of 2 feet above e highest known water. These figures have been used in the following estimat f yardage and cost, although present levee practice would be in favor of a hi r grade:

Section No. 1. Length, 67 miles; earthwork, 3,335,521 cubic yards; clearing. 4

acres. Cost, at 20 cents per cubic yard, $700,640.20. Average cost per mile, $10,457.

Section No. 2. Length, 56 miles; earthwork, 1,503,206 cubic yards; clearing, 652.3 acres. Cost, at 20 cents per cubic yard, $326,733.20. Average cost per mile, $5,835.

Section No. 3. Length, 55 miles; earthwork, 2,222,526 cubic yards; clearing, 667.2 acres. Cost, at 20 cents per cubic yard, $471,193.20. Average cost per mile, $8,567.

Adding 20 per cent. to the above for raising grade line wherever necessary, and for other contingencies, the total estimated cost is $1,798,279.92.

The closure of this front should begin at section 1, where the expenditure of a given amount of money will accomplish the greatest amount of benefit in restraining the overflow into the St. Francis Basin.

Further details are given in the report herewith of W. M. Rees, assistant engineer.

SURVEY FOR LOCATION OF A LEVEE TO CONNECT THE HELENA AND LACONIA LEVEES.

At the time the allotments for levees were made available in November, 1890, very little was known of the country through which the extension of the Helena levee would run, and the local levee board were unable to give sufficient information upon which the location of the proposed levee might be based. A hasty examination was therefore ordered made prior to the opening of the bids for levees on November 18, 1890, and was completed November 17. The examination was necessarily very cursory, and left comparatively untouched the problem of draining the interior of the Helena Basin, which was presented by the proposed closure of Long Lake and Old Town bayous. A further examination being necessary, a second party was formed under the immediate direction of Mr. W. M. Rees, assistant engineer, and took the field December 30. The question of drainage was thoroughly examined and the survey extended down to and across Yellow Banks Bayou, the latter point being the lower terminus of what might be called the Helena levee, or the point to which the levee should be extended to protect from overflow the area included in the Helena Levee district. After the survey had been extended to this point, it was decided to make a hasty examination as far down as the new Carson Loop, as the proper location of the latter with reference to its future extension northward as a part of the White River front system could be best determined with the information which such an examination would supply. This examination was completed on the 13th of February and the party disbanded.

The details of the survey and a description of the line followed is given in the report of W. M. Rees, hereto appended. In general terms, the proposed location follows what is considered a safe distance from caving banks, utilizes, as far as it is practicable and economical to do so, the old levee, and crosses the points instead of following the banks around the bends. The total length of the line surveyed, from the present terminus of the levee, 15½ miles below Helena, to the upper end of the Carson Loop, is 33 miles. Of this, 15.4 miles is enlargement and repair of old levees, and 17.6 miles of new levees. The total estimated yardage of new work is, in round numbers, 1,380,000; of enlargement, 1,000,000; and muck ditch, 100,000; making a total of 2,481,866 cubic yards. The total yardage in the old levee, which has been deducted from the total embankment in levee, is 468,000. These estimates are based on a grade of 3 to 4½ feet above the high water of 1890, the highest known in this vicinity, crown width of 8 to 10 feet, and side slopes of 1 on 3.

The territory to be protected is about 20 miles long from north to south and 10 miles wide between the Mississippi and White River. It is sparsely settled, many plantations having been abandoned on account of the frequent overflows.

PLANT.

Fair progress has been made during the past year toward rehabilitating the plant of the first and second districts. The steamer *Kirns* has received new boilers and boilers are under contract for the steamers *Titan* and *Graham* to be completed and in place before the beginning of this season's work. The *Titan* is a new vessel, completed in 1889, and as the hulls of the *Kirns* and the *Graham* received thorough repairs during the previous fiscal year all three steamers should be serviceable a number of years without extensive repairs. The steamer *Itasca* has been docked and her hull painted and upper works repaired and painted. She will also require a new boiler at an early date. The steamer *Abbot*, whose deck and upper work were recently destroyed by fire on the night of September 20, was rebuilt and again ready for duty November 6. The old headquarters boat *Amelia* having become unsafe from the rottenness and weakness of her hulls, and the estimated cost of repairs being deemed excessive, was dismantled and quarter boat No. 29 was remodeled to suit the immediate requirements of a headquarters boat. The latter though small will answer very well until a suitable headquarters boat can be provided. Two cracked and leaky water cylinders on two of the hydraulic graders will be replaced by two new and stronger ones.

In addition to the above other repairs of a minor character have been made. The principal work in hand at the present time is the reconstruction of twenty old district barges. As only the sound parts of the old barges are retained the reconstructed barges will be practically as good as new. As a rule, only the bottoms, bottom gunwales, and bulkheads of the old barges are retained. This work is done at from $1,000 to $1,200 per barge, or at less than half the cost of a new barge. Four mattress barges, each 120 feet long, were advertised for May 5, 1891, and only one bid was received, viz, that of David S. Barmore, for $5,320 for each barge delivered at Plum Point. This price being considered very high, if not excessive, the bid was rejected and steps taken to reconstruct the old mat barges in the same way as the district barges. This can be done at less than one-half the price of the bid above quoted, and the reconstructed barges will be practically as good as new. This method of utilizing the more lasting parts of old plant a second time is possible only by means of the dry dock, the utility and economy of which in maintaining a plant has been so clearly demonstrated. Care is taken in every case that nothing but perfectly sound timber is retained in the reconstructed barge. In addition to the above, two of the old district barges will be lengthened during their reconstruction to 120 feet and given additional strength for use as mooring barges.

About three-fourths of the total number of the pile drivers in the district are unserviceable on account of decayed and leaky hulls. I estimate that fifteen pile drivers would satisfy the probable needs of the two districts for several years to come, and this number it is proposed to put and keep in repair. As to the remainder of the pile drivers I recommend, if they can not be disposed of by transfer to some public work where they might be needed, that they be dismantled and the hulls sunk. The machinery, which is all serviceable, could be stored on barges or on the bank, or sold. For the coming season's work it has been arranged that forty of the general service barges shall go to the third district, and thirty-eight to the first and second districts. This latter number, with the twenty now in repair, will be sufficient for the probable needs of the work planned for this year.

The other classes of plant not already mentioned, quarter boats, commissary and receiver of materials store boat, machine shops, hydraulic graders are in good condition.

The exhibit herewith shows more in detail the extent in cost of the repairs which have been made during the year.

LEVEES.

The following sums were allotted for levees in the second district from the river and harbor act of September 19, 1890:

Upper Mississippi levee district	$90,000
White River Basin	180,000

and were suballotted by the levee board to the following localities:

Upper Mississippi levee district.

	Cubic yards.
Section 60, about	74,000
Section 61, about	55,000
Section 16, H (Hushpuckana Crossing), about	41,000
Section 19–20, H (Apperson Field), about	61,000
Section 17–18, H (Robertsonville), about	50,000
Section 67, about	64,000
Section 66, about	71,000
Section 65, about	57,000

White River Basin.

Extension of Helena levee southward from its present terminus	$80,000
Repairing and strengthening the front line of the Laconia Circle, and for extending the levee northward as far as the funds would allow	100,000

All work under these allotments was advertised on November 8 and bids opened November 18, 1890. Eleven bids were received, and the lowest in each case accepted, except that for the Helena, which was rejected as too high. The latter was advertised a second time, and bids therefor opened December 19, 1890. The prices again being deemed too high, all bids were rejected and the work postponed until after the high-water season. A copy of the abstract of bids is herewith.

The early part of December found all the contractors on the ground ready to begin work. A great effort was made to get an early start, so as to take advantage of the favorable weather, which usually prevails during the month of December. The

forces were at first too small, but were gradually increased on the demand of the engineer in charge until they were sufficient to insure completion of work on contract time, March 1, 1891. The calculations for force required were based on 30 cubic yards per day for each wheel scraper, and 20 working days in each month. Fair weather prevailed and good progress was made till about January 10, but after this date the rainy season set in, greatly retarding the work at all points, and in some of the worst localities practically suspending it altogether. The total precipitation probably did not exceed the average for this region, but the rainfalls came with such great frequency that the borrow pits and embankment were kept in a boggy and unworkable condition over three-fourths of the time. After the rains came the seep water and overflow which further suspended the work till the river fell within its banks. The contracts were extended from March 1 to May 1, and again from May 1 to July 1, 1891.

The following is a brief statement of the character and extent of the work done under these contracts:

Section 60.—The piece of levee under enlargement was 4,800 feet long, with side slopes of 1 on 3, and a grade of 2 feet above highest known water. The average height of the old levee above the ground was about 11½ feet, except at the crossing of Grants Pass, where for 200 feet the average height was 25 feet. The crown width of old levee was 10 feet for a distance of 1,600 feet from the lower end, 8 feet for the next 1,100 feet, and 10 feet over the remaining distance of 2,100 feet.

The repairs and enlargements are:

1. A muck ditch, 6 feet deep, 6 feet wide at bottom, and 10 feet wide at top, excavated at the base of the old levee on the land side and refilled with selected buckshot material.

2. Enlarging the upper 3,200 feet of the old levee to a height of 4 feet above highest known water, and to a crown width of 10 feet, and side slopes of 1 on 3.

3. A banquette on the land side, 3,035 feet long, at the crossing of Grants Pass, where the levee is very high. The uniform width of the banquette is 40 feet with a side slope of 1 on 3 and a top slope for drainage of 1 in 20.

The total estimated yardage in this levee is 53,000, of which 32,000 had been placed up to the end of May, 1891.

Section 61.—This piece of levee is 3,300 feet long and about 18 feet high above the surface of the ground, with a crown width of 10 feet, side slopes of 1 on 3, and a grade of 2½ feet above highest known water. The repair and enlargement consisted of—

1. A muck ditch 6 feet deep, 6 feet wide at bottom, and 10 feet at top, excavated along the base of the levee on the land side and refilled with selected buckshot material.

2. A banquette on the land side 40 feet wide raised to a height 9 feet below the top of the levee.

The total yardage was 37,672 and was completed in the early part of this month.

Sections 66 and 67.—The piece of levee under enlargement is 9,000 feet long and has an average height of 8 feet above the surface of the ground and 2 feet above highest known water, with a crown width of 8 feet and side slopes of 1 on 3. The work consists of—

1. A muck ditch 6 feet deep and 6 feet wide at bottom and 10 feet at top, excavated at the base of the old levee on the land side and refilled with buckshot material thoroughly tamped.

2. An enlargement to a height of 4 feet above high water and to a crown width of 10 feet, and slope of 1 on 4 on the land side. All low places on the land side were filled in with a banquette.

Total yardage, 100,000, of which 98,000 had been placed up to June 10.

Section 16 H (Hushpuckana Crossing).—The work is limited to the piece of levee 1,200 feet long across Hushpuckana Creek. The height of the old levee was 25 feet above the bottom of the creek and 2 feet above high-water mark. Crown width was 10 feet, river slope 1 on 4, land slope 1 on 3. There was also a banquette 40 feet wide on the land side, raised to a heighth of about 12 feet below top of levee. There was sufficient earth in the old levee for the purpose of stability, but further treatment was deemed necessary to correct the seepage, which has always taken place at this point to an alarming extent.

The new work consists of—

1. A muck ditch 6 feet deep and 6 feet wide at bottom, and 8 feet at top, excavated in the old banquette at the junction of the latter with the main levee, and refilled with good material.

2. A second muck ditch 10 feet deep, and 10 feet wide at bottom and 20 feet at top, at the base of the old banquette, refilled with good material.

3. Enlargement of the old levee to a crown width of 12 feet and height of 4 feet above high-water mark, with a land slope of 1 on 4.

4. A new banquette 40 feet wide, covering the second muck ditch.

Only a small piece of the large muck ditch has been excavated and filled to date,

and it is doubtful if the ditch can be dug at all on account of seep water. Should this be impracticable the ditch will be omitted altogether and a proportionately larger banquette made.

The total yardage in the work described is 41,000, of which about 20,000 was placed up to June 10.

In addition to the above, and under the same contract, a muck ditch 6 feet wide at bottom, 10 feet on top, and 6 feet deep, has been excavated and refilled at the base of the levee, below Hushpuckana Crossing, for a distance of 1,600 feet, the object being to reduce the amount of seepage.

Sections 17–18 H (*Robertsonville*).—This is a piece of levee 4,700 feet long, in what is known as the new Robertsonville Loop. Height of old levee above surface of ground, 12 feet, and above high-water mark, 1¼ feet. Crown width, 10 feet, and side slopes 1 on 3. The work consists in raising the grade to a height of 4 feet above high-water mark, preserving the same dimensions of crown and side slopes.

Total yardage 50,000, of which about one-third had been placed to June 10. The enlargement is from the river side of levee, and many of the borrow-pits are not yet in a condition to be occupied.

Sections 19–20 H (*Apperson Field*).—This piece of levee is 7,365 feet long, and is also a part of the new Robertsonville levee, and has approximately the same dimensions. The new work consists in raising the grade to a height of 4 feet above high water, preserving the old dimensions of crown width and side slopes. Total yardage in contract, 50,000, of which about one-half has been placed.

WHITE RIVER BASIN.

Laconia Circle.—The work consists in closing crevasses and enlarging the old levee over a distance of 90,300 feet, of which 59,600 feet lie below the town of Laconia, along what is known as the front line, and 30,700 feet north of the same point. The latter piece of enlargement terminates at the Desha County line, and from this point the line has been extended northward 6,000 feet by means of a new levee placed at a safe distance back from a caving bank. Of the 59,600 feet below Laconia 51,500 consisted in enlarging the old levee and 8,100 in closing crevasses, of which there were five, four below Henrico and one near Laconia Landing. In addition to the five crevasses named there were about twenty small breaks in the levee made by the high water of 1890, and of the old levee only one point, and that for a short distance only, was above this flood. The dimensions of the old levee varied greatly, but in general it may be stated that the grade was from 0 to 3 feet below high water of 1890; crown width, 1 to 6 feet; base, 20 to 50 feet; slope 1½ to 1, to 2½ to 1; height above surface of the ground, 3 to 10 feet. In the new work and enlargement the levee has been brought to the following dimensions: Grade, 1.5 feet above high water of 1890; crown width, 4, 6, and 8 feet, depending on height of levee; base, 35 to 90 feet; slopes, 2½ to 1 to 3 to 1; height above surface of ground, 7 to 14 feet.

The total yardage which it will be possible to place with the funds available will range from 400,000 to 450,000. The work should be within a few days of completion by the close of this month if the promised progress is made.

ROBERTSONVILLE CREVASSE.

This crevasse occurred on the night of March 11, and is located about three quarters of a mile below Hushpuckana in the levee known as the new Robertsonville Loop. The discovery was made at midnight, at which time the width was estimated at about 75 feet. Chief Engineer Dabney, of the Upper Mississippi Levee district, having determined upon an attempt to close it, requested this office for assistance, and with the approval of the president of the commission aid was offered to the extent of furnishing the necessary plant, the levee board paying for the labor and material. None of the district steamboats being available a tug was specially chartered for the purpose, but before the plant and material could reach the crevasse the idea of closing it was abandoned and the work was limited to an attempt to hold the ends of the levee and prevent any considerable widening of the crevasse. The usual temporary revetment of bagging, sand bags, and fascines loaded with sand bags were used around the ends of the levee, and two pile dikes, one on each side of the crevasse and about 600 feet apart, were built on the river side of the levee to check the current around the ends. The dikes consisted of four rows of 4 by 4 inch scantling with about 2 feet between rows, the intervals between rows being filled with bags of earth, the whole being suitably braced together. The dikes were located perpendicular to the levee and extended out as far as the depth would allow. The crevasse gradually increased in width to about 550 feet on March 28, after which the caving practically ceased.

The crevasse was a great surprise, as the pressure upon it was not great and the levee was regarded as one of the finest on the river, being built of buckshot ma-

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terial, and having a crown of 8 feet and side slopes of 1 on 3. There was no evidence of seepage or other defects to suggest the need of any precautions. The theory that the levee had been cut was very generally entertained at first, but gradually gave way to the more probable one that the levee had been undermined by the action of the current along the front. One of the old borrow pits directly in front of the crevasse was scoured out to some depth during the flood of 1890, and the probable explanation of the crevasse is that this scouring action continued during the present flood, gradually enlarging and deepening the hole, and finally undermining the levee itself. An inspection of the crevasse since the decline of the river within its banks shows the hole to be much larger than anticipated, being about 550 feet in diameter and extending through the gap and about 25 feet beyond. A new loop to close this crevasse is now under contract with the local levee board.

HIGH-WATER PROTECTION.

The lumber and sacks used at Robertsonville Crevasse were paid for by the Government, the levee board furnishing the labor. A close board fence was built in front of levee at Pushmataha Landing (359½, L) and a log boom in front of Eagle Lake Levee (306, L) to protect against wave wash, the Government furnishing the material and the levee board the labor. Sacks were supplied to the Helena board for the protection of their levee at Williamson's House (309, R), the labor of placing them being furnished by the local board. A small amount of protection work was done on the Laconia Circle, the Government furnishing both labor and material. As soon as the water rose high enough to suggest the necessity of patrolling the levee I had guards placed in the vicinity of all the levees under contract with the United States. These were withdrawn on the Mississippi side of the river as soon as practicable after receipt of a copy of the Commission's resolutions, requiring that such service should as a rule be performed by the local authorities. There being, however, no effective local levee organization on the Laconia Levee, a small Government patrol was maintained during the entire season over that portion of the levee under enlargement by the United States .The total amounts expended on levee protection were $6,005.18 in the Upper Mississippi Levee district, $2,617.88 at Laconia, and $473.07 along Helena Front.

A small gap in the Plum Point Levee near Gold Dust was repaired at an expense of $30.

CONDITION OF RIVER FOR NAVIGATION DURING THE YEAR.

As the river did not reach a low stage during the usual low-water period the navigation was excellent throughout the year.

A few reports of depths less than 10 feet have been received, but upon personal inquiry among a number of the most experienced pilots I am led to conclude that the pilots reporting lesser depths than 10 feet did not find the deepest water in the channel and that at no time during the past low-water season was there less than this depth over all the bars.

The usual financial exhibits are herewith.

Amount that can be profitably expended during the fiscal year 1892-'93 for channel works, $1,000,000.

Very respectfully, your obedient servant,

S. W. ROESSLER,
Captain of Engineers.

Gen. C. B. COMSTOCK,
President Mississippi River Commission.

APPENDIX D 1.

REPORT OF MR. AUG. J. NOLTY, ASSISTANT ENGINEER, ON WORK AT PLUM POINT REACH.

AMELIA, ARK., *May 20, 1891.*

CAPTAIN: In compliance with the instructions contained in your letters of May 13, and 15, 1891, I have the honor to submit the following report of operations at Plum Point Reach for the year ending May 31, 1891. The portion of the river covered by this report extends from one mile above Daniels Point to Craighead Point.

DIKES, ELMOT, AND ISLAND NO. 30 CHUTES.

The last annual report of Capt. Smith S. Leach, Corps of Engineers, U. S. Army, the officer then in charge of this district reported these dikes within a few days of completion. Elmot Chute Dike was completed on the 12th of June, 1890. In Island No. 30 chute the front row of dike, consisting of clusters of three piles each, had by the 2d of June, 1890, been carried across the 220 feet of deep water still remaining open. No sooner had this gap been closed when the pressure of accumulating drift and strong current began to push this unsupported front row out of alignment to such an extent that the piles began to break off, and on the morning of the 3d a clear opening of 90 feet had been made. The balance of this row gradually broke away until the gap attained a width of 200 feet. The depths ranging from 16 feet below zero at front or upstream row to 57 feet below zero at fourth or downstream row, with the water rushing through the gap with great velocity, the officer in charge of the district decided to await a more favorable stage of water before undertaking the closure of the gap. In the meantime a project for the closure was submitted by the assistant in charge, and having been approved by Capt. S. W. Roessler, Corps of Engineers, U. S. Army, then in charge of this district, work was begun on the 7th of July, 1890. This project contemplated leaving the line of dike and to effect a closure by a salient whose apex lying 75 feet above the front row of the standing dike would bring the whole new structure into comparatively shoal and easy water. The original dike foot mattress extending 75 feet above the front row, no new mattresses were considered necessary. In addition to the usual set of stringers and braces near the top of dike a secondary set was put on this new work at about the 15-foot plane, thus transmitting any strains from impact or pressure throughout the whole structure rather than letting the front row take them all without receiving any material support from the work behind it. The closure of this gap was completed by the end of the month and remained closed until February 3, 1891, when the accumulated drift again broke through, leaving a clear gap of 275 feet in the dike, with about 50 feet of each end of standing parts badly broken up. Nothing has been done toward reclosing this gap, nor would it be advisable to do any further work at this site by reason of the great depth of water which would always be a menace to the permanency of the structure. It should, however, be borne in mind that while a break in a dike rapidly forms a deep hole immediately below and, if close to bank, causes extreme caving, the experience both in this and Elmot chutes has been that these effects extend only a very short distance below the break.

Elmot Chute Dike remained in good condition until the 24th of November, upon which date a break occurred where the structure crossed the deepest water, or about 400 feet out from the Elmot Bar Bank. Owing to high stage of river prevailing at the time, together with much floating drift, no attempt to close this break was made until the middle of December, when two pile drivers begun the work of closure and strengthening of the Elmot Bar end. The work was completed on the 5th of February, 1891, since which date, despite an immense accumulation of drift, no further damage has been observed at this place. Two other small breaks, however, have occurred in this dike since the closure of the main gap. Nothing has been done toward closing these breaks. In every case where a break has occurred an examination of the wreckage shows plainly that the initial break at least was caused by the weakness of the piling. After a gap has been made the rush of water through it no doubt rapidly excavates a deep hole below the foot mattress, which later gradually settles down as the material under it flows into the excavation, and the adjacent piles having their penetration reduced, their buoyancy finally draws them out, and thus the gaps are widened. A peculiar phenomena was noticed at one of the breaks in the Elmot Chute Dike, namely, that part of the standing dike adjacent to the break was pushed out of alignment, with all piles standing and the different rows preserving their parallelism. The part of the dike thus affected has since gone out.

From observations made at these two dikes I am led to the following conclusions, namely, that with the material heretofore used it will be difficult to maintain a high water or 33-foot plane dike long enough to accomplish desired results without heavy expenditure for repairs. Too much reliance has been placed on the drift collected in front of a dike to make it impervious and cause rapid deposits. True, an accumulation of drift will greatly aid a dike, but it is also a continuous menace to its stability. A mid-stage dike constructed of brush cribs founded on floor mattresses where the elevation of the bars is up to or above mid-stage, and of pile dike across the deep water, the piles of which are so driven that the clusters of the second and fourth rows stand between those of the first and third rows, or, in other words, that 2 clusters of first, 1 of second, and 2 of third row stand in quincunx order, would in my opinion be more easy to maintain. The pile dike might in addition have on the downstream row a curtain of wattling to induce more rapid deposits. The dike foot mattress or floor mats should be at least 200 feet wide and the shore protection at the roots of dikes extend at least 400 feet below the last or downstream row of piles

If something could be done to neutralize the dangerous eddies and whirls which invariably form at the foot of a revetment another danger would be removed. In all deep-water dikes there should in addition to the usual bracing be a secondary set near the low-water line. No piles that have been cut more than 3 months prior to date of delivery should be accepted.

REVETMENT, FLETCHER BEND.

The unrevetted part of this bend, 3,800 feet long, was cleared of standing timber on three different occasions, namely: In June a strip 3,000 feet long and 100 feet wide; in August another similar strip, and in January, 1891, a strip 150 feet wide, 3,000 feet long. This clearing was done in order to prevent formation of snags, and the repetitions were required on account of rapid caving of bank. Stone to be used in the revetment of this bend is now being unloaded behind the protected bank.

REVETMENT, ASHPORT BEND.

As an initiatory step toward the revetment of this bend to Gold Dust Landing the bank is being cleared of all standing timber for 150 feet back of the present bank line. About 25 acres of clearing will be required.

REVETMENT, OSCEOLA BAR.

The protection of the lower part of this bar became imperatively necessary by reason of extensive caving and the consequent rapid recession of the shore line. This threatened to return a large volume of the river into the almost closed Bullerton Chute. The original project contemplated about 7,000 linear feet of revetment, but the indications at present are that but little if any more than the 5,000 feet already completed will be required.

Active operations were begun on November 8 by beginning the grading of the bank with the hydraulic jet. This work was merely a test to demonstrate whether or not the bank, which was very sandy, could be thus graded. Two days' work answered this question in the affirmative, and hydraulic grader No. 2 was put in commission, and began work on the 11th. The pile driver also continued grading, except when it was occupied in driving the abutment piles. In the meantime a part of the brush contractors' force and outfit having arrived, they were furnished a quarter boat belonging to the United States, and located near the proposed work. Construction of the first mattress was begun on the 14th. Owing to incomplete organization of the contractor's force, and consequent shortage of material, the swinging into position was delayed until the 18th. On the same day the river began rising rapidly, bringing down much drift. The run of drift increased until the 23d. The river was covered with it. The drift boom, however, protected the mooring barges and mattress, though the boom had frequently to be relieved by clearing away the accumulating drift. The drift boom consisted of 600 feet of old barges, with timber heads every 10 feet along the outstream gunwale, to which were fastened one-half inch chains hanging in festoons, their bights being 5 feet below bottom of barges. These bights soon become choked with drift, and thus prevent any more from passing under the boom.

The lower boom barge rests against the outer mooring barge, projecting a few feet beyond it, while the upper boom barge rests against the bank.

Progress in mattress construction, at first slow on account of an entirely inexperienced force, gradually increased as the men became more familiar with the work. At first the unit of day's work per man was 0.83 linear feet of 200 feet mattress, while toward the end of the first mat it was 1.7 feet. The first mattress, 1,100 by 240 feet, was completed on December 2, but by reason of the nonarrival of stone was not sunk until the 4th. The shore work had been during the mattress construction carried forward apace with the latter, so that after the mattress was sunk this section was completed except ballasting of the upper shore work. This first section completed lies 1,200 feet above the foot of the work and the protection work was begun here because this place was the most threatened. Before the mattress was sunk some caving took place at its head, which necessarily caused a steeper than the usual slope for about 150 feet. A pond in rear of this work was drained by placing a 12-inch box culvert with the necessary screens at the intake and apron at the outlet under ground. This drain has so far worked well.

Work was pushed with as large a force as could be economically employed with the limited plant available. On the 17th of December, Mr. C. W. Sturtevant, assistant engineer, having completed the work in Hopefield Bend, reported here with plant and a skeleton organization. His force was rapidly filled up and he at once begun construction of mattresses, shore work, and cribs at Section No. 3.

The river began rising toward the end of the month, bringing down much drift, and for the balance of the season the difficulties and risks of the work were greatly increased.

River mat No. 2 was sunk on December 19, No. 3 on January 5, and No. 4 on January 13. All river mats were 1,100 feet long and from 200 to 240 feet wide.

In addition to the usual bank protection, four brush and stone crib dikes to close chutes were constructed. Each was founded on a floor mat. Their location and dimensions are as follows: Between head of Bullerton Towhead and small towhead 1,008 feet long, 20 feet wide, 11 feet high. Between foot of Osceola Bar and head of Bullerton Towhead, 312 feet long, 35 feet wide, 5 feet high. At section No. 3, Osceola Bar, one 100 feet long, 40 feet wide, 4 feet high, and one 100 feet long, 32 feet wide, and 3 feet high. A small towhead at head of Bullerton Towhead was also revetted around its head and a supplemental mattress 312 by 125 feet for the large crib dike constructed. The method of construction mainly followed is that laid down in "details of construction," now in your possession, whose essential features are that the work from the outstream edge of river mat to upper edge of shore work is continuous. At parts of sections No. 3 and No. 4 this method could not be followed on account of the low banks, which were almost submerged by the rapidly rising river before the river mats were had. All work projected for the season was completed by the night of February 6, by which time the river had attained the 22-foot stage with water enough in sight to bring it up to the bank-full stage. The work as completed covers 5,000 feet of bank from the head of Bullerton Towhead up, and protects what was the most rapidly caving bend on the reach. Not only did this rapid caving threaten to seriously deteriorate the crossing below but, what was equally serious, it would have ultimately reopened Bullerton Chute, where the closure works were weakened from age, and would not have been able to withstand any large influx of water and drift.

YANKEE BAR CHUTE.

Nothing has been done toward the closure of this chute, although a project for a light dike was submitted and approved, and piles for the work purchased. These have all been expended on repairs to Elmot and Island No. 30 chute dikes. There appears to be no present necessity for this work.

OPERATIONS WITH SAND PUMP.

The plant for this work consists of one 12-inch square Ball automatic cut-off engine, one 12-inch discharge centrifugal pump, 1 hoisting engine, one 4-inch discharge steam pump, 2 pile-driver boilers, together with the necessary derrick and hoisting gear, the whole founded on a condemned pile driver rebuilt for that purpose. In order to furnish the maximum amount of sand that the pump might be able to lift, an apparatus consisting essentially of a revolving scraper attached to the suction pipe and operated by power furnished from a small 4 by 6 inch engine was tried. This device was abandoned by reason of its difficult manipulation and a double three-quarter-inch jet working in the suction was substituted. This furnished all the sand the pump was able to lift. After considerable experimenting with the outfit it was taken behind Elmot Dike and an attempt to sink drift was made. There not being enough discharge pipe on hand, 100 feet of box culvert was made and added to it. It soon became apparent that the power plant was insufficient for working the pump at its proper speed. A pile driver was brought up, coupled to sand boat, and an additional supply of steam obtained from its boiler. This gave better results, but it was evident that the engine was overloaded. The discharge pipe being too light, several joints collapsed when the pump was suddenly stopped; this was remedied by the insertion into it near the pump of a piece of 2-inch pipe 4 feet long and open to the atmosphere. This prevented the formation of a vacuum and the consequent collapse; though large quantities of sand were pumped on the drift for 11 days, no visible results became apparent. The increased current consequent upon a rapidly rising river no doubt dissipated large quantities of this material. On the eleventh day of the trial both boilers of the sand-pump boat were badly bagged and unsafe for further use in that condition. Nothing further has been done with the outfit since. The experiments have demonstrated, firstly, that no satisfactory results can be obtained by pumping on floating drift, except it be in water unable to transport sediment, unless it is first overlaid with a more impervious covering than the drift itself affords; secondly, that the discharge should take place not less than 100 feet above the dike, and that to avoid weakening the dike by robbing it of the support derived from the deposits sand should not be taken closer than 125 feet in rear; thirdly, that an engine developing 100 horse-power with 80 pounds of boiler pressure is required; and, fourthly, that discharge pipe, light, yet strong enough to re-

sist external atmospheric pressure, and with flanged instead of telescopic joints, be provided. The proper conditions for the successful working of this method of sinking and holding drift would be, drift resting on bottom, no appreciable current and plenty of sand within easy reach behind the dike. A combination of these would be rarely found in practice; on the contrary at the very place where it is most desired to sink the drift, *i. e.*, in the deeper parts of the chute, currents strong enough to transport sediment are encountered, while the sand to be pumped is usually so far off as to require excessive length of discharge pipe. The favorable conditions mentioned above existed to some extent in front of Bullerton Chute, Dike No. 2, when in the latter part of 1888 the steamer *Success* was pumping sand there.

LEVEES.

The only repairs required by the levees on this reach was the filling in of two faults near Gold Dust, Tenn., caused by the storm of March 24, 1890; 200 cubic yards of filling, at 15 cents per yard, were required. At other exposed places the planters interested in the maintenance of levees stood ready to protect them if required. Just below Island No. 30 Chute dike a large piece of levee has caved in. This caving was induced by the break in the dike; no other damage has been sustained. In this connection it might be stated that the people on the Arkansas side have always shown a more willing disposition to coöperate in the preservation of levees than on the Tennessee side.

REPAIRS TO PLANT.

This work has been continued from June 1, 1890, to January 28, 1891, when the repair force was disbanded. Repairs were resumed on March 23, 1891, and have been continued since. The principal work since the resumption has been the reconstruction of district barges, of which 20 will be rebuilt; 2 mooring barges will also be constructed by taking 2 district barges, lengthening them to 120 feet, and otherwise changing and strengthening them. The district barges when rebuilt will be practically as good as new ones. The cost ranges from $1,000 to $1,200, according as more or less of the old barge can be utilized. Usually the first gunwale strake, the bottom, floor stringers, and transverse and longitudinal bulkheads are found to be good, and sometimes the rakes and rake timbers also. The steamers *Kirns*, *Graham*, and *Itasca* have been thoroughly repaired. The former has a new battery of boilers, the *Graham* is now having hers repaired at Memphis, where the *Titan* also is awaiting a new set, and a new flue boiler is recommended for the *Itasca*. The launch *Abbot*, whose entire upper works were burnt on the night of September 20, was rebuilt and again ready for duty on November 6.

The dock constructed in 1888 has since been in almost constant use, has worked admirably, and has cost but very little for repairs.

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CARE OF PLANT.

The plant is divided into two divisions, one along the Arkansas bank at Lynch Landing, and the other and larger at Island No. 30. Headquarters are at the former, where also the repairs are made. At the Island No. 30 division there is laid up among some serviceable plant all the unserviceable recommended for condemnation and awaiting final disposition. Steps are now being taken with a view of consolidating the serviceable part of the plant along the Arkansas bank. This has been delayed in hopes that some final disposition of the unserviceable plant would shortly be made. The consolidation of the fleet will reduce the expenses of the care of plant.

CONDITION OF PLANT.

As intimated above a large part of the plant is unfit for service in its present condition. Much of it will cost large sums for repairs, and for some of it there would be no use even if it were serviceable. Notably is this the case with pile drivers, of which not more than 12 will probably ever be in commission at one time. Of mattress barges there is but 1 out of the 8 that could be made serviceable at a reasonable cost. Of mooring barges there are 2 belonging to second district; these are no onger considered safe. There are also 2 general service barges which were used last eason for this purpose. These, with some repairs, are good for another season's ork. Quarter boats, steamers, 10 pile drivers, 3 hydraulic graders, 1 derrick boat, sand-pump boat, 2 store and supply boats, 2 machine-shop boats, 1 headquarter at, 3 barges, 1 kitchen and bake shop boat are in good condition.

The former headquarters boat *Amelia* (or No. 2), being no longer considered safe and the estimated cost of repairs being considered more than it would be prudent to spend on such an old vessel, it was decided to change one of the quarter boats into a headquarters boat. Quarter boat No. 29 was decided on after being thoroughly repaired and, changed to suit her new purpose, is now known as *Amelia No. 2*. The boat, though rather small, is convenient and comfortable.

PRESENT CONDITION OF WORKS.

With the exception of the dikes in Elmot and Island No. 30 chutes, the works are in fair condition. Those constructed since 1885 are in very good condition, having suffered but slight damage.

At Daniel Point an enlargement of the fault noticed after the subsidence of the 1890 flood is noticeable; this fault is close to the head of the work and at the place where during construction so much trouble was encountered with large pockets of yellow sand. The fault consists in two sags and a slight rupture of the revetment. When the contemplated extension at the head is begun the new work should run down far enough to cover these faults. The balance of the Daniel Point work is in first-class condition. At Fletcher Bend all work is in fine shape. This work derives additional importance from the fact that two novelties were introduced, namely, the interrupted revetment and the protection of the above water slope by a stone pavement without the usual substructure of brush and poles. Two floods of long duration have passed since the interrupted revetment was constructed, and the unrevetted blocks of banks from 300 to 400 feet long stand to-day almost in the same condition and shape as they were left by the construction parties in 1888. The block at Elmot, 500 feet long, has caved somewhat at its lower end, which is the head of section E. The upper end of the caving would just about reach a point 400 feet below the foot of section D. Whether this would indicate that the limit of protective influence exerted by the revetted section above is 400 feet I am not prepared to say. When the work at section E was begun it was found necessary to use sluice boxes for the grading of the first 150 feet at its head, because thick layers of fine sand were encountered; considering this, and the fact that the material composing the bank as exposed at the 300 and 400 feet is much less friable and not so easily eroded, we may with equal justice assume that the caving here is due to composition of bank and not to length of block. Should any more interrupted revetment be constructed I would recommend the grading of the unprotected bank. The 1,000 feet, commonly called the pavement, is in fine shape and entirely covered with silt. As this piece of bank lies in the deep bight of the bend, and as very little strain is against it, it would, until tried at some more exposed place, be rather premature to venture an opinion as to its stability. It may, however, be accepted as a fact that a very flat slope is necessary for this kind of revetment. The reasons are that when much seepage water is running out the slopes become quite soft, and stone lying on a steep slope would probably begin to slide with the soft material. The brushwork can not slide as long as the transverse cables hold.

Plum Point revetment is somewhat broken up at its foot, caused by excessive caving of the unprotected bank. At Osceola Bar the revetment is undamaged. Crib No. 2 should be extended about 50 feet upstream to cover some scouring out that took place while the work was awaiting stone for sinking last February. There should be some additional ballasting done here, as is now being done at Fletcher Bend. Bullerton tow-head revetment is unchanged and in fair condition, as is also the old work at upper end of Osceola Bar and Fletcher Bend. Osceola and Bullerton chutes are practically closed at the 10-feet stage, there being no measurable discharge through them at that stage.

UNLOADING OF STONE.

Thirty-two thousand cubic yards of stone are to be stored here for use in the coming season's operations; 12,000 yards will be stored behind the protected bank at Fletcher Bend and 20,000 at Daniel Point. As the handling of stone has heretofore been very expensive, an unloading device has been constructed, which is unloading the stone at the present low stage of river for less than 15 cents per yard, or at about two-fifths the cost of unloading with wheelbarrows. The device consists of an overhead 1-inch steel wire rope fastened to a tree on the bank, running from thence to and over a sheave about midway up the mast on the derrick boat, thence down through hollow gudgeon at foot of mast and thence to engine. Upon this cable runs a traveler, to which hangs suspended a carriage carrying 1 yard of stone. The traveler is hauled out and in by the engine. As the cable is tautened, it raises the carriage, and when slackened lowers it to deck of stone barge, when the empty one is unhooked and a loaded one hooked on. As there is but little lateral movement to the device, a portable track is laid on the barge and the carriages are provided with

trucks, thus enabling them to be run from one end of the barge to the middle or to the opposite end. When everything works well 2½-minute trips are made by the carriages. The dumping is done automatically at any place on the line desired. A second machine is now being constructed in order to prevent a possible barge famine at the quarries. Of course the machines are equally applicable to reloading the stone on the barges.

GENERAL REMARKS.

When the short piece of Plum Point revetment was constructed the Island No. 30 crossing struck fairly against the bank to be protected. Now that the crossing has moved farther down and strikes the unprotected bank an extension of the revetment downstream about 1,000 feet is suggested. This would, I think, effectually check all further caving liable to deteriorate the Plum Point crossing. At the foot of section E, Fletcher Bend, considerable caving took place after the subsidence of the last flood. This is gradually extending downstream, and may suggest the necessity of an extension of section E. The slopes used during 1888 and 1889 were 1 on 4. This was changed in 1890 to 1 on 3, a change which seems to be a retrograde movement. At places where, owing to caving or sloughing off of the bank during construction, we were necessarily compelled to adopt a steeper than the 1 on 4 slope, notably at Daniel Point, faults in the otherwise perfect work are visible. I believe that the life of a revetment depends on the flatness of the slope. The revetment constructed during 1890–1891 being all laid on the steeper slopes, and being in exposed situations, ought soon to demonstrate the truth or falsity of this position. No loss of revetment work has been sustained during the year nor during the two previous years. This no doubt is due to improved methods of construction, to the use of steel shackle and mooring lines, and the use of drift booms. At Osceola Bar only, while working on the second section, did we have a favorable stage of river. During construction of the balance of the work it was a continual contest with rising river and large quantities of drift. Despite the drift boom and the steel ropes the strains were so great that on one occasion a ¾-inch steel rope, and at another a 1-inch one parted.

It is hoped that at the end of the coming season's work an equally satisfactory showing can be made.

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Respectfully submitted.

AUG. J. NOLTY,
Assistant Engineer, in charge.

Capt. S. W. ROESSLER,
Corps of Engineers.

APPENDIX D 2.

PAPER BY MR. AUG. J. NOLTY, ASSISTANT ENGINEER, ON DETAILS OF CONSTRUCTION OF BANK PROTECTION AS PRACTICED AT PLUM POINT REACH, 1890.

1. The crest line of slope is staked out for the entire length of the proposed work. The slope is 4 to 1, counting from the zero contour. The bank is then cleared from the edge to 50 feet back of the crest line.

2. As soon as a sufficient length of bank is cleared grading will begin. If more than one grader is available, they will take such intervals as will permit them to finish at about the same time. If, however, it is desired to begin mattressing as early as possible, the intervals must be shortened. There are two methods of grading, namely, by hydraulic jet and by sluicing. The latter method is only permissible, on account of its greater cost, where the nature of the soil precludes the use of the jet. Sluicing is done as follows: Sluice boxes are laid on the slope and up to the face left by the grader. A line of hose is run from a pile driver up to the top of slope and into the first sluice box. From 12 to 20 men are distributed along the line on top of the ungraded bank, who shovel the dirt into the boxes, whence it is washed out with ıe water furnished by the pile driver. About 6 feet wide, the entire length of the ope, is taken for each shift, and care must be taken to slope the high parts of the ut a little to decrease the danger of caving on top of the men. As soon as this block is cut down to the proper grade the boxes are moved and a new block cut down; ust sufficient water must be pumped to easily move the material. One man is staoned at the boxes, whose duty it is to prevent choking up. At the discharge end of e boxes, if necessary, brush must be laid under the overfall. This is done to prent caving. With the hydraulic graders two jets are worked at 160 to 170 pounds mp pressure. With the pile drivers only one jet can be worked by the pump.

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After grading, the bank is dressed by hand, all holes being filled up with brush and dirt. When sluicing is resorted to, the latter operation is not necessary, as the slope is finished up as the grading proceeds.

3. Simultaneously with the grading, or at any time after clearing of bank, all snags lying along the site of the proposed mattress are removed by blasting from the surface, by pulling out with a steamboat where possible, or with the aid of a submarine diver. The latter method is costly, but is the best where there are many snags. The first and second methods, of course, can only be applied to those visible; the last method, provided we have an honest diver, gets them all. In most cases, however, the first and second will give reasonably good results.

4. As soon as 100 feet or more of bank is graded, and snags removed from in front, the mooring barge abutment and the abutment piles will be driven. The abutment is constructed as follows, viz: Two piles, 15 feet apart, and parallel with the bank line, are driven from 10 to 15 feet inside the low water or zero line; two clusters of two piles each, all driven at the zero line, and directly opposite to the two first piles; an inclined brace or strut then connects each cluster to its companion pile in rear. The twin piles must be at least 10 feet above the prevailing stage of water to allow for any rise in the river. The rear piles may be 5 feet lower. The braces must be sawed off flush with the face of the twin piles to allow the free oscillation of the mooring barge. The twin piles are driven one behind the other and parallel with the long axis of the brace. This abutment must be driven high enough upstream so that when plant is swung into position the head of mattress will be on the line designated for it. Single piles 100 feet apart and at least 10 feet above the prevailing stage are driven on the zero line for the entire length of the proposed mattress. The object of the abutment and the abutment piles is to keep the inner edge of the mattress on the zero line throughout the varying stage of water. After the completion of the work these piles are removed; otherwise, they would, when submerged, form dangerous obstructions to navigation; where the bank is tolerably bluff, and not caving, the rear row of piles in the abutment may be omitted and the braces footed directly on the bank.

5. While the abutment is being constructed the two mooring barges, having been firmly lashed end to end, are brought alongside the bank above the abutment. Outside of these barges, parallel with them and with the ways touching the gunwale of mooring barges, is brought the mattress or weaving barge. The head lines, consisting of one 1¼-inch flexible wire rope for the present upstream, later the outstream end, two 1⅛-inch flexible wire ropes for the next two, and three 1-inch for the balance, are run to trees, sound stumps or dead men well back from the edge of the bank and temporarily fastened. The three large cables will be on the upstream barge, and the three smaller on the downstream one. When in position, the upstream barge becomes the outside one. Mattress head lines are also run out as follows: Two flexible 1⅛-inch wire cables, two 1-inch, and one ⅞-inch, in the following order; the smaller next to inner edge, then the two 1-inch, followed by the two 1⅛-inch ones, with, as near as possible, equal intervals between them, being, however, careful to have the outstream cable close to outer edge of mat. These last cables must be passed under the mooring barge and brought up on the outside gunwale, where they are temporarily secured like the mooring barge head lines. All these cables come with an eye spliced in one end. These eyes are the river ends and are secured as follows: On the mooring barge, on the upstream side, are large timber heads fitted with heavy iron bands, whose upstream ends are formed into eyes, having a 1¼-inch bolt passing through them. Between these eyes the eye of the cable is brought and the whole thing bolted together. To fasten the mattress head lines, straps of sound 2-inch manilla rope are used, which are fastened to the mattress head and run back into the mat, at least 25 feet being securely fastened by means of a pin shackle of requisite strength. In handling these cables care must be taken not to kink them nor to fasten them around anything less than 18 inches in diameter. While the lines are being run out a party has begun on the mattress, the first step in this operation being the construction of the head.

6. The head of the mattress is constructed as follows: Hard wood poles, as large as can be conveniently handled by a gang of men, and reasonably straight, are laid in two lines on the ways over and parallel to the inner (or upstream) gunwale. These poles lap each other 10 to 15 feet, the two lines breaking joints. Where they lap they are spiked together with 8 inch by ¼ inch spikes every 2 feet, and are then tied together with No. 12 galvanized wire at intervals of 10 feet, except at the laps, where there should be at least two ties. This line of poles must of course be equal in length to the width of mat. Upon these poles the first set of weaving poles, one for each way and parallel to them, are spiked with two 8 inch by ¼ inch spikes for each pole, and lashed with No. 12 wire. (The butt-end is the end to be fastened.) Another set of head poles similar in all respects to the bottom set, is then spiked and lashed on top of the weaving poles. The whole head thus constructed is then securely wired together. The weaving poles are live willow or cottonwood, reason-

ably straight, 4 to 6 inches diameter at butt and from 25 to 30 feet long. To facilitate weaving all knots are trimmed off and the top and bottom roughly shaved with a draw knife. A cable made of 8 strands of No. 12 wire is fastened around the head of the mat at every third weaving pole and run up alongside of them, being stapled with two staples to the pole. These cables are made about 48 feet long, with an eye in each end, then cut in the middle of their length, thus making two cables, each having an eye for looping together. After each shift of mat a new length of cable is looped on the preceding one. Thus making 10 continuous cables through the mat. They give strength to the mat and hold up the brush in case the weaving poles should break in launching. Weaving can now begin.

7. The brush used for weaving is live, straight willow of any length above 25 feet, being not less than 2 inches nor more than 4 inches at the butts.

A full complement of men for a 200-foot mat is 54, divided in three equal gangs, each one under a master laborer, and the whole under charge of a foreman. Each gang is distributed as follows: 5 men are on the brush barge and pass the brush to the weaving party, which numbers 12 men; 1 man is on top of mat where he packs the brush, as the weavers push it down, with a wooden maul. Each gang has about one-third of the width of mat.

The brush barge is brought on the outside of mat barge about midway of the two ends. One barge loaded with poles is hung to each end of mat barge. A coil of 2-inch rope is placed on each end of mat barge, and the free ends fastened to the proper timber heads of the mooring barges. The ways are slushed with axle grease or tallow, to reduce friction of brush against them both in weaving and launching off; 27 weaving poles are used in a 200-foot mat. They are placed alongside the ways and their upper ends rest in brackets bolted to the upright posts.

The brush is passed by the brush men to the weavers, who come in pairs, and by them taken to the proper place. The butts are placed over one weaving pole and 2 feet beyond them the brush passes over the next pole, under the third, over the fourth, and so on, the light tops being always left on top. A strip of 5 feet in width is woven this way, when for the next 5 feet the butts are reversed. Thus, in every alternate strip of 5 feet the butts point one way and in the opposite direction in the other strips. The weaving is continued to within 2 feet of the top of poles which will give about 22 feet of mat. The next step is to swing into position.

8. Two coils of 2 inches and one of 1½-inch manilla rope are used for swinging around, the smaller line being used on the downstream, or what will soon be the inside end. The shore ends having been fastened and the mooring mat and brush barges having been lashed to close contact, the whole outfit is dropped down until the lower end of mooring barge is within a few feet of the upper end of abutment. The upstream or outside lines will be now slowly slacked off and the whole thing allowed to swing nearly, but not quite perpendicular to bank and held there. The slack of the mooring barge cables is now taken in from the bank so as to get as nearly as possible an equal strain on all. They are then fastened permanently with clamps furnished for that purpose. Five 1¼ inch-manilla lines, 100 feet long, are fastened equidistant on the mat, and pass up underneath to the way supports, where they are fastened to kevels. These are used to hold the mat from sliding off the ways prematurely. They are slacked off in launching and must be shifted along the mat from time to time as weaving progresses. The shift of mattress previously made is now slid off until the head of mat touches the downstream gunwale of mooring barge, when the slip lines are put on.

9. The slip lines are 1½-inch manilla rope, about 125 feet long, and number 18 for a 200-foot mat. Each has an eye large enough to pass over the proper timber heads, at one end. This eye is placed over the timber head, the free end is passed under the head of mat and up again on its downstream side and then hauled taut and fastened on its timber head. The mattress head will now hang in 18 slings. When these slip lines are all adjusted the mat is further slid off until the downstream edge is over the upstream gunwale of the weaving barge. The office of these lines is threefold; they prevent the current from forcing the head under at the first shift; they hold up the head well out of water during construction, and are used to lower the mat down any required depth in sinking. They are of the utmost importance and should be carefully watched. The mat is now slid off until its downstream edge is about half way between the end of the extended ways and the upstream gunwale of mat barge. This will equal about 22 feet of mat at a shift. A new set of weaving poles is now spliced to the projecting ends of the first set, the butts of the new set being spliced to the tops of the preceding one, after having been pushed into the mat about 3 feet, thus making a lap of 5 feet. Two 8-inch by ¼-inch spikes and two wire lashings are used to each splice. The weaving now continues, as before described, to within 2 feet of top of poles, when another launch is made, and so on, until the full length of mat is made. While the poles are spliced on, the brush men place a sufficient number of poles on top of the mat, to be afterward wired down, as described further on. The mattress-head cables should now be fastened to mat, as

described above, their slack hauled in from the bank, being careful to strain them equally, and the ends permanently and securely fastened. The caution given above to be careful in handling the wire cables is here reiterated. Do not get any kinks in them, make no sharp bends, use nothing less than 18 inches in diameter around which to fasten them, and when ungalvanized cables are used keep them well greased with heavy dope. When taken up they should be well washed and greased while being wound on their respective reels. The mooring barges, it will be remembered, are not yet quite in their proper position, *i. e.*, they are not quite perpendicular to the bank. As the construction of the mat progresses, and more strain is thrown on the cables by the increasing amount of mattress afloat, the head cables are tautened, and in most cases this taking up of slack will bring everything into its proper position. If not, the cables must be slacked off sufficiently to bring it so. The general foreman should personally inspect all the fastenings at least once a day, and see that each cable bears its proper strain. When the plant is in proper position, the brush barge is close up to and parallel with the weaving barge, and the two pole barges hang end on, one from each end of the weaving barge.

10. The top grillage is begun as soon as two or three shifts of mat are launched off, and is laid as follows: A line of poles is laid over the weaving poles, lapping each other (butts to tops) from 6 to 8 feet, and wired to the weaving poles every 4 feet by lashings 2 feet long, made of two strands of No. 10 wire. Transverse poles 8 feet apart for the first hundred feet of mat, and thereafter 16 feet apart, are laid in a similar manner and lashed to the longitudinal ones wherever they cross by lashings 2 feet long made of four strands of No. 12 wire. This grillage strengthens the mat and also forms cribs for holding the stone ballast. The first set of transverse poles along the inner edge are hard wood and are only 8 feet apart throughout the length of mat. Where these come between the 16-foot spaces they are only one pole in length. They are used in connecting the shore mat to the river mat.

11. The construction of shore mat, which must keep progress with the river mat, is done by a gang of from 30 to 40 men under a foreman and one master laborer. The water space to be spanned in doing this part of the work varies according to the stage of river from 0 to 60 feet, as the inner edge of river mat is at all stages kept by the abutment piles over the zero contour line. The shore mat is constructed as follows (a small flat being used for convenience whenever it can be easily floated between the mat and the bank): Hard wood poles of the size of the weaving poles are lashed to the mat with three No. 12 wire lashings 2 feet long, and spiked with two 8 inch by ½ inch spikes. Willow poles (or cottonwood) are spliced to these until they reach up the slope about 40 feet. Alongside and fastened to each one of the hard wood poles, is a cable made of eight strands of No. 10 wire, one end of which is fastened to two of the adjacent weaving poles, the other being fastened to the willow extensions on the slope. Upon these transverse poles are laid longitudinally willow or cottonwood poles 8 feet apart, beginning with the first set about 4 feet from the edge of the mat. We thus form a grillage of 8-foot squares. The latter poles are wired to the former at their intersection with lashings of No. 12 wire, 2 feet long. The longitudinal poles are carried in lines 8 feet apart up to top of slope, and on their lower sides, 8 feet apart, are driven stakes 2.5 feet above ground, to the top of which is fastened loosely a lashing of No. 12 wire, 2 feet long, whose bight has been first passed under the pole. These stakes are carried down to the pole nearest to water's edge. They indicate the corners and are a guide in laying the top grillage, besides holding the lashings for tying together the whole work. Upon this foundation a layer of brush is laid diagonally and with the butts all toward top of slope and breaking joints throughout, except at top of slope, where the butts all come on a straight line corresponding to the crest line, and for the first length of brush next to the river mat where the butts all abut against the edge of mat. A second layer of brush is laid upon the first in an opposite direction, with the butts pointing to top of slope and breaking joints. The diagonality of each layer should be such that the two layers form a right angle with each other. The upper line of butts of top layer, as well as the bottom line, are like those of the bottom layer, *i. e.*, a straight line. On top of this brush are laid poles of willow or cottonwood in longitudinal rows 8 feet apart, directly above the lower set. The lashings held by the stakes are now used to tie the whole strongly together. On top of these are laid transverse poles 8 feet apart where there are corresponding bottom poles, *i. e.*, from the inner edge of river mat 40 feet up the slope and 16 feet apart thereafter, which are firmly tied to the longitudinal ones. It should have been stated that as soon as the slope has been dressed brush and poles sufficient for the shore work should be unloaded near the top of bank in convenient piles. It requires 1¼ cords of brush to the linear foot of river mat 200 feet wide, and 1½ cords of poles to every 12 cords of brush. The same quantities hold good for the work from inner edge of mat to top of slope. As fast as river mat and shore work is finished, traverse cables, made of eight strands of No. 10 wire and 60 feet long, with an eye in each end, are run across the entire width of the mat every 16 feet, and carried to the top of the bank, when they are hauled

taut and fastened to trees or stumps, or in the absence of these, to dead men. These cables are lashed to the mat with wire every 16 feet. They are made 60 feet long for convenience of handling, and are, of course, looped together to form a continuous cable. Two men can fasten these cables as rapidly as required.

12. Longitudinal cables on river mat. These cables, which are a continuation of the mattress-head cables, are furnished ready made of the following diameters: two $\frac{5}{8}$, two $\frac{1}{2}$, and one $\frac{3}{8}$ inch, each 1,200 feet long. They come in coils, and must be mounted on reels before using. As soon as4 00 to 500 feet of mat is made they are run off the reels, beginning with a $\frac{5}{8}$-inch cable on the outside or river edge of mat. The whole cable is reeled off the reel but the inner end kept on the mooring barge where these reels are set up. After being run down toward and close to the weaving barge the spare cable is nicely coiled down and tied for future extension. Just above the coil the cable is securely fastened to the mat with a wire lashing and a specially made clamp. The party then goes back to the mooring barge and fastens a tackle to the free end, hauling the cable as taut as 10 men can do it. The tackle must take hold far enough below the mattress head to allow the end of cable to be fastened without giving back any slack. The cable is then fastened to the mat every 16 feet with a wire lashing and clamp. The second $\frac{5}{8}$-inch cable is next run out and fastened where the second head cable takes hold, then follow the two $\frac{1}{2}$-inch and finally the $\frac{3}{8}$-inch. As weaving progresses the cables are extended until the mat is finished, when the ends are securely fastened around the foot of the mat. The first hauling taut, as has been stated, is done from the mooring barge end of cables, all subsequent hauling must of course be done from the mattress by hauling downstream, as now the upper 400 feet are rigidly fastened and the slack must be carried toward foot of mat. When these cables are all run out they lie about as follows: one $\frac{5}{8}$-inch cable close to outer edge of mat, the other $\frac{5}{8}$-inch about 30 feet distant from the first, the third, a $\frac{1}{2}$-inch one, 37 feet from the second, the other $\frac{1}{2}$-inch one 38 feet distant from the third, and the $\frac{3}{8}$-inch one 42 feet distant from the fourth, or 45 feet outside the inner edge of mat, all fastened down to mat every 16 feet perfectly taut throughout their length and all securely fastened around the head and foot of mat. A gang of 10 men under an experienced sailor may run these cables and attend to all head and other lines.

13. When about 600 feet of mat is completed, ballasting may begin. For this purpose a loaded stone barge is brought up outside the mat and hung to the mooring barge by a 2-inch rope. It is held close to mat by breast lines. Cottonwood run plank 16 inches wide and 3 inches thick and 24 feet long run from the barge to mat. From the foot of these barge planks a continuous run of cottonwood plank 10 inches by 2 inches by 18 feet is laid across the mat. According to the strength of the gang there may be from two to four of these runs, from 10 to 15 men to a run. These men wheel out the stone and dump their loads along the transverse poles, loading the entire floating work until only the poles are above water, being careful to load the 50 feet next the bank heavier than the balance. This will be of advantage in sinking the mat. There is one foreman and one or two master laborers to this gang. The men on each run must go out and return together. The runs are taken up, the barge dropped its length and runs relaid as necessary. The shore work will not be ballasted until the river mat is sunk, except in cases where stone is piled on the bank, in which case the shore work as well as part of the river mat can be ballasted from the bank.

14. Sinking of the mat. This may be called the final as well as the most important operation. As soon as the mat is completed and ballasted, a loaded stone barge, preferably one of the smaller ones, is brought up to the mooring barge. A line is run from its head to the inshore capstan of the mooring barge, and another from its lower end to the outer capstan. A good man is stationed at each slip line, who obeys only the word of the general foreman during this operation. Stone is thrown on the head of mattress, and as soon as the strain on the slip lines increases by reason of the added weight they are carefully slacked off a little. The men at the inshore capstan begin to haul the head of the stone barge gradually over the submerged mat, the lower end is also gradually hauled up, the object being to bring the stone barge squarely across the mat. Stone is being continually thrown over as directed and the barge hauled over until this is accomplished. The line from the downstream end of barge must be shifted to another capstan as the barge proceeds inshore, being held with a line while the change is quickly made. Another stone barge has, in the mean time, been brought up and as soon as the first is in position the second is brought up to the out stream end of the first, hauled around across the mat, and both securely lashed end to end. In the mean time a coil of 2-inch rope has been placed on the inner end of the first and the outer end of the second barge and the end of each fastened to ts proper timber head. A long 1-inch line also runs from the inner end of the first arge ashore, where a lot of men will be ready to haul the inshore end of the barge ownstream, as in most cases the water near the bank is without current. The towoat now makes fast with one line to the outer end of the outside barge. The posi-

tion now is as follows: the two stone barges lie across the submerged mat parallel and close to the mooring barges held there by a 2-inch line at each end of the coupled barges. The slack, or spare line, lies nicely coiled up ready to be paid out. A skillful linesman is at each end. The men on shore have hold of the 1-inch hauling line, the steamboat hangs from and close to the outer end of the stone barges and lies with the current. One man is at each slip line and a line of men is distributed along the upstream side of stone barges and another along the downstream side. The foreman and master laborers take positions where they can oversee the men. The general foreman is on the mooring barges watching the slip-line men; after these are let go, he runs along shore directing the operations. The general foreman now gives the word to throw the stone, and as soon as he thinks the head of the mat has enough he orders the linesmen on the stone barge to slack away. He then gives the word and all slip lines are let go simultaneously. The steamboat's duty is to keep the barges away from the bank. The slip-line men as soon as disengaged assist the men on shore in hauling down. The linesmen must slack off so as to keep the barges always nearly square across the mat until near the end where the steamboat lets go, and the outer end of the stone barges is allowed to swing around over the mat and to the bank. Everything must move promptly and without hitch in the whole operation.

15. As soon as the mat is down the sailor gang takes up all the lines. The mattress head cables are taken up first by hauling on the pin lines that are loosely fastened on the mooring barge. These lines pull the pins out of the shackle and set the cables free from the mat. The mooring barges are then allowed to swing to bank and all cables are reeled up on their drums, being washed and oiled as taken in. The stone barge can now be brought to bank and balance of shore work ballasted if not already done. About 2 cubic yards of stone will be required for every linear foot of work.

16. In the foregoing description of mattress and shore work it has been supposed that the bank can be graded before any other work is undertaken. This is generally the case, but it will happen that a bank to be operated upon is caving so rapidly as to make it necessary to lay the foot mat first. It is obvious that in such a case the shore work has to be deferred. The abutment and abutment piles are driven and the mattress constructed as described, except that the hard-wood poles along inner edge are omitted and only the regular top grillage laid. After the mattress is sunk the bank is graded and the shore work laid down to the water's edge. A connecting mat is then made to connect the shore work with the submerged river mat as follows:

17. The weaving barge is brought up alongside and parallel to bank, with its upstream end over the head of mat, and a mattress built like the river mat, except that it has a lighter head, and, of course, no mooring barges are used. Instead of the heavy wire cables some of the wire strand is run from the head up to top of bank and fastened thereon. Five ⅝-inch cables will be sufficient for every 200 feet of mat. Two or three cables are also run from the upstream edge of mat to shore to prevent the current from taking it downstream. The head of mat, when launched off, must lap well (4 or 5 feet) over the shore work. When a shift is to be launched off the mat barge must be sparred away from the bank. Enough mat is thus made until when sunk it will lap over the river mat 4 or 5 feet. From 40 to 70 feet will be the the usual length. The mat barge is then dropped down its own length and another connecting mat made, being careful to have a close joint between the two connecting mats. This operation is repeated until the foot of mat is reached. These mats are sunk as fast as made.

APPENDIX D 3.

PAPER BY MR. AUG. J. NOLTY, ASSISTANT ENGINEER, ON DETAILS OF CONSTRUCTION OF PILE DIKES, AS PRACTICED AT PLUM POINT REACH, 1890.

1. The line of anchor piles, upstream edge of dike foot mat, and front row of proposed dike will be designated on the banks by plain white signals visible from the opposite bank. When one bank is too far distant, as, for instance, when work is done in the main river, piles must be driven a little beyond the extreme outer end of dike to correspond with the signals on the bank. These piles will carry white signals. The general foreman will see that the alignment as indicated by these signals is preserved; more especially should the upper edge of foot mat and front row of dike be carefully kept on line. In constructing the dike the successive rows are laid off from the preceding one with a graduated stick or tape line.

2. The anchor bents are driven on the proper line. In shallow water (less than 10 feet) one pile may take the place of a bent; in less than 20 feet two piles are driven, the first one on the line, the other 20 feet above, and the two braced together. When

there is more than 20 feet of water a cluster of two piles is driven on the line and one pile 25 feet above. These are braced together. The distance between the piles and bents is 50 feet. To each single pile before it is driven are fastened two cables made of 8 strands No. 10 wire 60 feet long, with a loop at each end. These, as well as all other cables fastened to piles, must be fastened about 20 feet from the bottom end of the pile. To each downstream pile of the bents two similar cables are fastened and to each upstream pile one. The cable from the upstream pile is carried to the intersection of brace and downstream piles, hauled taut, and securely fastened. One cable from downstream pair of piles is carried to the upstream pile and fastened at the intersection of brace and pile. All other cables are temporarily fastened with one spike at the head of their respective piles. These cables will be used as anchor cables of the mat. The anchor piles and bents should be driven to at least 12 feet above the prevailing stage of water. The upstream pile may be 5 feet lower and the braces should be inclined upstream. The line of anchor piles should be 150 feet above the front row of dike, and the line of upper edge of foot mat 75 feet above the front. Penetration of piles, 20 feet.

3. As soon as a sufficient number of anchor piles are driven construction of foot mat is begun. These mats, which are 200 by 200 feet, are constructed similarly to the river mat, except that no hard-wood poles are used and no wire head cables are run out. The mooring barges are held with short 2-inch manilla lines to the anchor piles and the cables on the piles will be the head cables for the mat. At the proper time these cables are brought up under the mooring barges and fastened to head of mat, being, however, careful to have the head of mat far enough above its line so that when the mat is sunk its head will be on the proper line. This allowance will of course vary with the depth of water. When the mat is completed it is sunk and the plant shifted in position for the next one. Care must be taken that each mat overlaps the preceding one about 5 feet. When this work is completed there will be a line of mat on the line of proposed dike 200 feet wide and as long as the dike or width of chute, with its upper edge 75 feet above front row of dike.

4. While these mats are being constructed the banks are being graded to the usual slope of 4 to 1 for a distance of 500 feet, beginning 150 feet above the front row. If plant is available, the construction of river and shore mat can proceed as soon as grading is completed and while the foot mats are being made. If not, the bank protection had better be put in before the dike foot mat. This 500 feet of bank protection is constructed precisely as described under "Bank protection," except that at a low stage of river the abutment and abutment piles may be omitted. It may often happen that the shore line is such that proper lead for the head cables can not be obtained. In such a case anchor piles in sets of two or three, according to depth of water, must be driven several hundred feet above the head of mat to which to fasten the cables. The object of this bank protection is to prevent any cutting around the ends of dike. In closing a chute it will usually be found necessary to build only one regular shore protection, that is, along the caving bank. The other bank is usually a long flat mud or sand bar, and here all that is necessary is to run the regular dike foot mat up to the top of bank.

5. The following list gives the outfit for one pile driver:

Anchors ....number..	3	Lanterns:	
Axes ....do...	2	Red ....number..	1
Bedding ....sets..	6	White ....do...	2
Blocks and tackle, 1¼ inches..do...	1	Lamps, bracket ....do...	2
Blocks, snatch, 10 inches.number..	2	Lead and line, 75 feet ....do...	1
Buckets, galvanized.........do...	2	Monkey wrenches:	
Boiler scraper................do...	1	15-inch ....do...	1
Brooms ....do...	2	10-inch ....do...	1
Cant hooks ....do...	2	Marline......................coil..	1
Capstan bars.................do...	2	Mop ....number..	1
Daily report banks, block....do...	1	Oiler ....do...	1
Files:		Oil cans, 5 gallon............do...	3
14-inch bastard ....do...	1	One man saw..................do...	1
12-inch round ....do...	1	Oars ....do...	6
Flue scraper ....do...	1	Oakum.................pounds...	10
Gauge glass, ⅝ inch..........do...	1	Pinch bars, steel ....do...	2
Hammer, machine...........do...	1	Pike poles ....number..	2
Hatchets ....do...	1	Pile-head follower...........do...	1
Hammer line, steel, ⅝ inch ..feet..	150	Packing:	
Hose:		Sheet ....feet..	2
2½-inch ....do...	100	Piston ....do...	10
1-inch ....do...	25	Hemp.....................do...	10
Jet pipes ....number..	2	Cotton stem ....ball..	1

Pile chains	number..	2	Seizing twine	ball..	1
Pump:			Spanners	number..	2
Lever	do...	1	Slice bar	do...	1
Valves	do...	6	Tallow cup	do...	1
Springs	do...	6	Time book	do...	1
Watch tackle	set..	1	Toggles, assorted	do...	10
Red lead	pound..	1	Vice bench	do...	1
Rope:			Water barrel	do...	1
1¼-inch (one piece)	feet..	300	Wrenches, assorted	do...	3
1½-inch, jet line	do...	125	White lead	pound..	1
1¼ inch pile line	do...	150	Cold chisels	number..	2
1-inch (one piece)	do...	200	Emery paper	sheets..	3
¾-inch (one piece)	do...	100	Oil:		
Spike mauls	number..	2	Lubricating	gallons..	1½
Shovel, coal	do...	1	Signal	do...	1½
Skiff	do...	1	Kerosene	do...	3

Monthly supplies for one fleet.

Waste	pounds..	4	Stillson wrench	number..	1
Soap	do...	5	Load clamp, 18-inch	do...	1
Tallow	do...	3	Rivets, angle iron	do...	6
Lye	do...	2	Bolts, angle iron	do...	6

6. As soon as 200 feet or more of dike foot mat has been completed pile driving on the dike proper may begin. The piles should be of cypress, cut not more than 1 year prior to delivery, should be reasonably straight, not less than 9 inches on top nor more than 20 inches at butt, and of such length as to allow a penetration of 20 feet into the bottom, with the tops of piles on an imaginary line 33 feet above the zero of 1879. The butt end of each pile is dressed to a chisel point to allow of easy penetration of mat. This is done when the pile is hanging in the leads. The jet pipe is fastened on one of the sides between the two dressed faces, so that the nozzle is a few inches above the bottom of pile. For this purpose there is attached to each jet pipe, 5 feet above its lower end, a toggle with a short piece (6 inches) of chain. This chain is spiked onto the pile with three 8 by ½ inch spikes and holds the pipe to its work. At the top, just below the hose coupling, the pipe is lashed to the pile with strands of old rope. A ½ inch line is fastened to the jet pipe below the coupling. This line passes to the winch head and is used for pulling up the pipe. The pipe is now lowered down, care being taken to have the pile on the line before it touches bottom. When it touches bottom, or before it is in deep water, a cable is looped around the pile and fastened with one 8-inch spike. (These cables in all cases should be 20 feet above bottom of pile.) The pile is now fixed in the middle of the leads and held there by means of removable toggles and a follower just below the head of pile. The pump is now started and the hammer lowered down on the pile. A few light blows will be necessary to drive the pile through the mat, after which, in sandy or soft bottom, the jet assisted by the weight of the hammer will usually drive the pile home. In clayey bottom, however, the jet does little good and hard driving is necessary. Quick, light blows will be more effective than heavy ones and less severe on the leads. Should the head of the pile become "broomed," a piece must be sawed off so as to get solid wood for the hammer to strike. Should the jet, as will sometimes happen, become detached before the pile has penetrated more than 16 inches, the pile must be pulled up and a new trial made. If impossible to pull it up, another pile must be driven in lieu of it. When the depth of water, counting from ordinary high water, is less than 20 feet, one pile in the front row and one in the second and third row will be sufficient. For more than 20 feet and less than 40 feet, two piles in the front and one each in the second, third, and fourth are driven. For more than 40 feet, three piles in the front row and one each in the second, third, fourth, and fifth rows are driven. Each pile, except those on the rear row, must have a cable attached to it, and after the piles are driven these cables are temporarily fastened to top of pile with one spike. The front row piles, as before stated, come up to the 33-feet plane, the second row will be 2.5 feet lower than the first, the third 2.5 feet lower than the second, and so on. The distance between rows is 25 feet, and that between bents is 7.5 feet. As soon as a driver has driven a sufficient length of front row a rider will be put up. These should not be less than 55 feet long and are fastened 2 feet below tops of piles. Cables made of 8 strands No. 12 wire, 20 feet long, with a loop in each end, are used.

The rider is lashed at each pile, or cluster of piles, and as many turns around rider and pile are taken as the length of cable will permit. Each turn is hauled taut by the steam winch and fastened with an 8-inch spike, and the looped end is securely fastened with two. These spikes are driven into the pile so as to leave 1.5 inch out-

side, and then clinched over the cable and bedded into the wood. The laps or splices of riders should be 15 feet long, the top or thin end of one lapping the butt end of the other. In order to preserve as near as possible a horizontal line with the riders the butt end is always lowered about 1.5 feet, so that the splices all come nearly on a straight line throughout the row. As soon as a piece of front row is thus completed drivers may begin on the second one, and as fast as a few hundred feet of this second row is completed the first and second rows should be braced together. The braces are short piles 30 to 35 feet long. They rest on top of the riders, butt ends upstream, projecting not more than 1 foot beyond the front piles, and are lashed to rider and piles with a cable made of eight strands of No. 12 wire 20 feet long, having a loop in each end. The braces should always lie parallel with the current, which usually brings them perpendicular to the line of dike.

It is very essential that the first and second rows should be braced as soon as possible, for should much drift lodge in front of the unsupported row it is almost certain to be forced out of alignment, if not entirely overturned. The third, fourth, and fifth rows are driven and braced as those in front advance. Usually work is begun at both ends of the dike, the drivers working toward each other. As the dike advances, and opening between the two ends is reduced, the current increases, and this makes the work very difficult in deep water; hence, if we are reasonably certain that the work can be completed before the water gets too low on the shoal places, the point of final closure may with advantage be located in shoal water. But there is always the risk of being driven away from here by the declining river before the work is finished. It even becomes necessary sometimes to do the shallow water work first of all. As soon as location of final closure has been determined, and if it lies in deep water, there should be constructed a supplemental foot mat 200 by 200 feet, which should be sunk at this place just below the main dike foot mat. Experience in Chute No. 30 has shown the necessity of this. Here the gap was of necessity left in deep water, and before this could be closed we had a hole just below the foot mat whose maximum depth was 49 feet below zero. On this line of front row the soundings at the time gave 35 feet, while on the fourth row we had 20 feet more. The current rushing over the mat cut out the soft bottom just below it, and as the hole deepened the soft material began to flow out from under the mat allowing it to sink, and badly breaking it up.

7. Where the dike crosses the deep water the distance between the bottom of river and the bracing on top of dike is sometimes as great as 50 feet. When drift is running the force of the current carries much of it under the top stratum lying against the dike, forming an almost impervious wall of drift, shown during the present low water to be as much as 12 feet deep. The pressure against the dike is therefore very heavy, and this pressure the front row has at certain stages to bear, without being able to derive any support from the dike in the rear. This pressure has become great enough to break off the front piles at about the 15-foot or mid-stage line. It has therefore been decided to run a set of secondary braces from every alternate bent through the dike. These braces are on the 15-foot line, and should preferably be of long piles. No riders are needed. Pressure against the front row will thus be transmitted throughout the dike.

8. When all the pile work has been completed the foot cables are adjusted. These cables are all carried to the rear row, hauled taut with the winch, and fastened around rider and pile. When the cables are not long enough, another one is spliced onto the one leading from the pile. At least three turns should be taken around the pile and rider, and each turn fastened with a spike, and the looped end with two.

9. The final operation is the trimming off of each row to its proper plane. This can also be done at any time before the cables are adjusted in order to utilize any spare labor.

GENERAL REMARKS.

The piles are usually received in rafts, each block of which consists of piles of equal length. A launch or steamboat serves the pile drivers with piles of required length. The general foreman keeps a record of the number of feet of piling used and of those rejected. These latter are held subject to the order of the contractor. To each fleet of pile drivers there is attached one fleet engineer whose duty it is to supervise the pile driver engineers and to see that the machinery is always in working order. He will see that all boilers are thoroughly cleaned out every Sunday morning. The general foreman will detail two laborers for each pile driver to help the engineer to clean out and refill his boiler. Two and a fourth hours are allowed for this, for which the laborers receive double time. The pile-driver foreman handles the engine in driving. In hauling cables he may let one of his men handle the engine. The engineer attends to the pump and boiler. The general foreman and the fleet engineer are each allowed a skiff and one skiffman. The code of signals is as follows: Want piles, blow two short blasts; want general foreman, three blasts; want fleet engineer, four blasts of the whistle. The crew of pile driver consists of one foreman, at $60 per month, one

steam engineer, at $50 per month, and four laborers, at $1 per day of eight hours. It has been found to be good policy to increase the pay of those foreman doing the most work to $65 per month, reserving, of course, the right to stop this increase whenever their work falls below what it should be.

The general foreman should carefully watch the pile driving and see that piles are given the proper penetration. Also that riders and braces are well lashed, and that all work is kept on the proper lines. Each pile-driver foreman makes daily reports, on blanks furnished to the general foreman; the latter condenses these and makes daily reports on blanks furnished to the assistant engineer in charge. A false entry on the pile-driver report is sufficient ground for summary discharge. The completed dike should be laid off in stations of 200 feet each, and periodical soundings taken along the rear row to obtain some idea of what the dike is accomplishing. As the rate of progress of the work varies with the depth of water, rapidity of current, and nature of bottom, no fixed standard of the number of piles to be driven by each driver per day can be established. In water less than 20 feet deep, having a sandy or soft bottom, from ten to twelve piles per day is a fair day's work. In deep water, strong current and hard bottom, this may fall as low as three piles. Hoisting up and fastening 10 braces or 3 riders, or adjusting 40 foot cables may be considered a day's work.

When the piles are furnished loaded on barges a pile-dropping gang of four men, in charge of a master laborer, will drop the piles off the barge and take them to the drivers. The cable-making party consists of two men, who have the proper machinery for making the cables. Two men can make all the cables for four pile drivers.

When a pile is longer than required the top should be cut off, and never the butt end except it be too thick to go between the leads. Anchor piles should be pulled up or cut off at a low stage of water, otherwise they will hold back a large amount of drift, whose sudden release by the breaking of these piles might damage the dike by impact.

APPENDIX D 4.

REPORT OF MR. W. M. REES, ASSISTANT ENGINEER, ON PROPOSED SYSTEM OF LEVEES ALONG ST. FRANCIS FRONT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 1, 1891.

CAPTAIN: I have the honor to report upon a proposed system of levees along St. Francis Front, Missouri and Arkansas.

A survey for this from Point Pleasant, Mo., to Council Bend, Ark., a distance of 200 miles, was made by Mr. S. E. Moore, assistant engineer, from October, 1888, to April, 1889. A profile of this survey has been made and quantities calculated, the results of which are incorporated in this report.

Point Pleasant was considered a good terminus on the north, for the reason that from this place northward to New Madrid, Mo., and a number of miles above there extends a ridge of high ground, forming a barrier to overflow. Above this ridge there is some low ground, over which the water can escape into the St. Francis Basin. In 1882 the estimated maximum escape was 88,000 cubic feet per second, and in 1883 45,000 cubic feet per second. This is supposed to go to the St. Francis through Little River and give no further trouble until it comes back again into the Mississippi at Helena.

Below Point Pleasant the escape is many times greater, reaching over half a million cubic feet per second a few miles below Memphis, Tenn.

The following table shows the estimated maximum escape along the line of the proposed levee, the divisions being laid out to show the nature of overflow:

Table of water escape, St. Francis Front.

Division.	Levee sections.	Miles below Cairo.	Flood of 1882. Outflow (cubic feet per second).	Flood of 1882. Inflow (cubic feet per second).	Flood of 1882. Net escape.	Remarks.
1	0-67	80-158	378,502	27,400	351,102	From Point Pleasant to the Plum Point system of levees of which 23 miles are built
2	90-146	170-216	20,362	15,805	4,557	From Craighead Point, the lower end of Plum Point levees, to the high ground at Bradley Landing; this high ground connects with the Marion-Crawfordsvill ridge.
3	146-201	216-268	167,310	184,771	-17,461	From Bradley to the end of the survey a Council Chute. The inflow includes Frenchmans Bayou below the end of the survey

The quantities in the above table are from the report of Chief of Engineers, U. S. Army, Part IV, 1885, page 2601, where the "water escapes" are given in numerous subdivisions and at numerous localities.

DISCUSSION OF THE OVERFLOW, BY DIVISIONS.

Division 1 furnishes fully two-thirds of the water escaping into the St. Francis Basin above the latitude of Memphis, and most of this is between Gayoso, Mo. (105 miles below Cairo, Ill.,) and Island 25 (145), only 72,000 cubic feet per second being the outflow above Gayoso. This overflow fills up numerous lakes and low places on its way to the St. Francis, the main drainage to which is through Pemiscot Bayou.

During a flood there is considerable inflow through Mill Bayou, at the head of the Plum Point Levee system, and this inflow is said to increase as the water in the river falls. The evidence here being that the escape of water above is greater than can readily pass into the St. Francis, a considerable portion being therefore returned to the Mississippi, hence the construction of a levee across the lower end without first cutting off the overflow above, would be disastrous to the lands in the former locality, which includes much cultivated lands in the vicinity of Osceola, Ark.

First. By impounding the water, probably causing it to raise higher back of the levee than in front.

Second. By holding the water on the lands for a long time after the river begins falling, as the drainage would be slowly toward the St. Francis instead of quickly to the Mississippi.

To confine the maximum amount of water in this division, with the minimum of cost, the levee should first be constructed between Gayoso, Mo. (105), and Barfield, Ark. (142). Next build from Gayoso to Point Pleasant (79); and lastly close across the low ground and back of Long Lake, at the lower end.

Division 2. the river banks in this division are quite high and there are no outlets of any size. The escape therefore is principally across points, again returning to the river a short distance below. There will be no risk in closing the entire front irrespective of any work above. No doubt the proper procedure would be to continue the levee from Craighead Point (170) south.

Wampanocka Bayou, at Bradley (215), might be left open until the levee is extended to Mound City (225), for it no doubt materially facilitates the drainage of the country when the river gets within its banks.

Division 3. The escape is chiefly at the upper end, exceeding 100,000 cubic feet between Bradley (215) and Redman Point (220). Most of this passes through Ten-mile and Fifteen-mile bayous, scarcely reaching the St. Francis proper during a large flood, but returns to the Mississippi at Council Bend (270), through Holtree and Frenchman bayous.

A levee along this front will restrain about 100,000 cubic feet per second, and the proper locality to begin work is at the upper end, Bradley to Mound City and thence southward.

The following estimate is from the survey made by Mr. Moore, the data used being, grade, 2 feet above high water, except at foot of bends, where it is raised from 6 to 12 inches; crowns, 6, 8, and 10 feet, depending upon height of levee; slopes, on each side, 3 to 1; muck ditch, 3 by 3 feet, and width of clearing, 200 feet.

To the embankment 10 per cent. has been added for extra work, road crossings, etc. The cost has been estimated at 20 cents per cubic yard for earthwork and $40 per acre for clearing.

St. Francis Front Levees.—Preliminary estimate of quantities and cost.

Division.	Levee sections,	Earthwork.	Clearing.	Cost.	Cost per mile.
		Cubic yds.	*Acres.*		
1	1–67	3,335,521	838.4	$700,640.20	$10,457.00
2	90–146	1,503,206	652.3	326,733.20	5,835.00
	146–201	2,222,526	667.2	471,193.20	8,567.00
Total		7,061,253	2,157.9	1,498,566.60	8,312.00

In confining such a large escape to the channel it is probable that the flood line ll be raised, at least for such time as will be required for the river to adjust itself the new conditions; hence in some localities, such as lower ends of bends, it will wise to raise the grade line. Therefore, it is suggested to add to the above estites of cost 20 per cent. This will make the total cost $1,798,279 92, and the rage cost per mile, $9,974.

DESCRIPTION OF THE SURVEYED LINE.

The line in general follows the high ground near the river, receding therefrom to what is considered a safe distance, in caving bends, and leaving the river at such places where badly caving banks closely approach lakes and low ground, and where a levee could not be moved back should danger arise, except by making a long detour. Wherever favorable ground has existed across points, the levee has been located there. This being but a preliminary survey, it is expected that a more thorough study of the ground will develop a better and cheaper line.

In many places the location was on old State and private levees; these, however, are small, and will require enlargement to two or more times their present size to bring them up to proposed sections. Twenty-three miles of good levee exists along the west bank of Plum Point Reach (section 67 to 90).

The greatest depth of overflow is between Barfield (145) and the head of Long Lake, and this only reaches 10 feet for two or three stations. The average depth along the entire line will not exceed 5 feet. From Pecan Point (196) south for a distance of nearly 4 miles the land is above overflow. The material along along the entire line is reported to be favorable for good levee work.

Respectfully submitted.

W. M. REES,
Assistant Engineer.

Capt. S. W. ROESSLER,
Corps of Engineers, U. S. A.

APPENDIX D 5.

REPORT OF MR. W. M. REES, ASSISTANT ENGINEER, ON LEVEE SURVEY, WHITE RIVER FRONT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 1., 1891.

CAPTAIN: In compliance with the instructions contained in your letter of December 20, 1890, to take charge of the location and construction of a levee on the "White River Front," and subsequent verbal orders to extend the survey to connect with the "Laconia system" of levees, I have the honor to submit the following report upon a preliminary survey:

During the latter part of December I organized a survey party for the purpose, which, including cook and watchman, consisted of 10 men. This force left Memphis December 30, 1890, on a quarter boat and was towed to Old Town Landing by the United States steamer *Kirns*, arriving the following day. The survey was at once begun, from the end of the completed levee, 15½ miles below Helena and continued to the head of the Laconia Levees, about 32¼ miles from the beginning, or 48 miles below Helena. The progress was necessarily slow, the season being rainy, the country unsettled and heavily timbered, and with numerous canebrakes, especially on the old levees, and the rising river flooded the bayous and low places and delayed the work.

The time occupied is distributed as follows:

Days worked		26
Days lost by rain	9	
Days lost moving quarter boat	3	
Days lost, Sundays	6	
Days lost in transit	2	
		20
Total		46

The method of conducting the survey was to locate lines by magnetic bearings, marking stations at each 100 feet with stakes, running careful levels and checking same at all available United States bench marks, establishing temporary benchmarks at about each half-mile, and taking elevations at all stations and high-water marks of flood of 1890 at numerous places, usually at each half-mile or less.

All old levees were occupied whenever they were at a safe distance back from the river, these were cross-sectioned to determine their volume, and the elevations of natural surfaces of ground taken on each side.

Care was taken to locate the lines on as high ground as practicable, keeping at a safe distance back from all caving banks, and to cut off points whenever feasible.

The territory to be protected is about 20 miles long from north to south by about 10 miles average width from east to west, lying between the Mississippi and White rivers; it is very sparsely settled, many farms having been abandoned on account of frequent overflows. There is considerable good land, much of which overflows less than 6 feet; these high lands generally skirt the lakes and bayous, of which there are many.

Long Lake and Old Town bayous drain into the Mississippi River during low water, but in time of flood the current is often reversed and the water goes to White River.

Below Old Town Bend the low-water drainage is into White River, though in high water stages, should White River be higher than the Mississippi, the current is reversed and the drainage is into the Mississippi. In fact the deep bayous connect the rivers, and the height of the one above the other determines the direction of the currents.

The principal bayous are, Yellow Banks, connecting with Allens (or Flat) Lake which connects with White River through Goslee Bayou, and Bee Bayou, which heads in a large swamp back of the bend of Island No. 65 and runs into White River.

In the bend of Island No. 68 there are several small bayous connecting with White River.

The flood water escape can not be even approximately determined, there being no data, but it is undoubtedly great at certain stages, as is evident by the numerous bayous and slashes into which the country is furrowed.

DESCRIPTION OF THE LINE.

From the end of the completed levee, 15¼ miles below Helena, Ark. (Station 765), the line follows an old levee to within three-quarters of a mile of Old Town Landing (325 miles below Cairo), having two intervening loops around breaks. From this point (Station 884) the old levee is abandoned, as it approaches too near the river in a badly caving bend, the distance back being from 350 to 700 feet for a length of over 1¼ miles; besides, to occupy the old levee would require a fill across Old Town Bayou, only 400 feet back from the river, which would be 270 feet long, 34 feet maximum height, containing, with 4 to 1 slopes, about 30,000 cubic yards, hence it was considered wise to make a long loop at a safe distance back from the river, and to cross Long Lake Bayou above its junction with Old Town Bayou, into which it discharges, thence follow up Old Town Bayou about 3,000 feet, crossing it about 2,000 feet inland, and, continuing the line back of caving bend, distant one-quarter of a mile and upwards, to meet the old levee again 5,700 feet above Yellow Banks Break. This loop is 15,500 feet long, on ground which overflows between 5 and 8½ feet. The two bayou crossings are each about 110 feet wide, 29 feet maximum depth below grade, and require about 12,000 cubic yards embankment each.

The proposed location will involve the excavation of a drainage ditch from Long Lake Bayou to Old Town Bayou; this will be about 4,500 feet long, and contain about 35,000 cubic yards.

A survey was made for this, and project with map submitted to you February 2, 1891.

From the lower end of the loop (Station 1039) the old levee was followed to Yellow Banks break.

The portion of levee from Station 765 to Long Lake Bayou (Station 914) is on the same location as that made by Mr. Henry Goodrich, assistant engineer, in November, 1890. This was examined and accepted. The old levee from Station 1039 to Yellow Banks Bayou (Station 1097), including loop, which latter could not be revised on account of high water, was surveyed by Assistant Engineer J. M. Kloster in 1887. This was examined, and no breaks or washes being found, the measurements and profile were accepted. Both Mr. Goodrich's and Mr. Kloster's work was recalculated to other slopes and grade line, their temporary bench-marks were rechecked, and high-water elevations of the flood of 1890 taken along their survey.

The break at Yellow Banks Bayou is a large one and the loop to clear it will require 800 linear feet of 20-feet levee, or about 48,000 cubic yards of embankment.

From this break (Station 1097) the line follows an old levee, from one-half to one ile back of the river, to Station 1305, above Modoc Landing (334). This portion has o small breaks in it.

At Modoc the line crosses the head of Glade Lake and for over 2 miles follows the e on a high ridge overflowing 5 to 6 feet and is from one-half to 1 mile inland. e overflow from Glade Lake is into Yellow Banks Bayou. A line was run between e foot of the lake and the bayou, and the crossing found to be so long and deep that as obliged to cross the bayou at Station 1441, where it is 115 feet wide and 28 feet ximum depth below grade; thence following a high cane ridge, where the overflow om 5 to 7 feet. the line recrosses Yellow Banks Bayou at Station 1534, where it is ut the same width and depth as above, and at Station 1555, about one-half mile from Hugheys Landing (337), it connects with the old levee.

The territory in front of Glade Lake was thoroughly explored, but a line here is not feasible on account of too close proximity to the river in a badly caving bend.

The double crossing of Yellow Banks Bayou will not interfere with the drainage, as both ends are open. In two places, one back of Hugheys Landing, and the other about 3 miles below, arms of this bayou were closed by the old levee, and the embankments are in good condition now.

From Hugheys Landing (337) to near the foot of Island No. 64 (343) the old levee was followed to Station 1765, or about 4 miles.

There are two levees here, but the front one is quite small and broken, whilst the back one is large and in good condition and nearly up to high-water marks, with only two small breaks. From the end of the old levee the line crosses School House Bayou, about one-half mile distant, and only one-quarter mile from the river. This crossing is 80 feet wide and about 22 feet below grade. Closing it will not interfere with the drainage. Thence for about 1 mile the line follows Allens (or Flat) Lake on high ground, about 5¼ feet overflow, to Station 1952.

From this point two lines were run, one in front and the other back of Bee Bayou swamp, which is back of Island No. 65 (345).

The lines compare as follows:

Lines.	Length.	Cubic yards.
Back line	19,019	342,200
Front line	12,379	328,000
Difference	6,640	14,200

The front line is over 1¼ miles shorter and contains 14,200 cubic yards less earth, but it is in front of a large cypress swamp, much of which overflows 20 feet, also on sandy soil, and 2,000 feet will require an embankment about 16 feet high. The back line follows the river side of a cane ridge, is on good ground, and has from 6 to 7 feet overflow; it crosses some small bayous and one large one (Bee Bayou) 115 feet wide and 22 feet below grade line. A somewhat better location of the front line could be had by coming within one-quarter of a mile of the river, but the bank is caving rapidly here, or near the upper end of the bend, whilst it has about ceased caving towards the lower end.

From the intersection of the two lines about Station 2035 the lines follow a high cane ridge, the overflow of which is from 3 to 5 feet.

At Upper Ludlow woodyard (347) the line approaches to within 1,200 feet of the river.

From Station 2199 two lines were run, one along the old levee to Ludlow Landing (360) and the other is a cut-off line which meets the old levee about 1¼ miles below Ludlow. The lines compare as follows:

Line.	Length, feet.	Cubic yards.
Front line	18,700	252,200
Back line	12,100	186,500
Difference	6,600	65,700

Although the front line occupies the old levee for the most of the distance, the yardage is greater, as the old levee is quite small, containing but 50,000 cubic yards.

Below the intersection of the front and back lines, the line follows the old levee for 1¼ miles, thence it runs back of the bend of Island No. 68 (363), distant about one-quarter of a mile inland, to an intersection with the "Carson Loop" levee.

METHOD OF PROCEDURE.

The White River front should be closed by following the present plan, viz: Extend the levee from its present terminus above Old Town southward to Modoc, and from the upper end of the Laconia system northward to Ludlow's upper landing, leaving the intermediate ground until the last, for here are two large bayous which will drain the flood waters quickly to White River.

The tables accompanying this report show in detail the quantities of earthwork and clearing required. The embankment has been calculated upon a basis of 8 to 10 feet crown, slopes 3 to 1 on each side, with grade line from 3 to 4½ feet above the high water of 1890, which was the highest known.

The muck ditch is to be large, equal to 3,000 cubic yards per mile section.

The totals are as follows, for a length of levee 32¼ miles:

	Cubic yards.
Enlargement	999, 232. 6
New work	1, 382, 513. 2
Muck ditch	100, 120. 2
Total	2, 481, 866. 0

The total yardage in old levee occupied is as follows:

	Cubic yards.
Above Old Town Landing	94, 304
Between Old Town and Modoc landings	225, 717
Between Hughey's and foot of Island No. 64	113, 225
Below Ludlow's	34, 964
Total old levee	468, 210

The line has been plotted on the charts of the Mississippi River Commission, scale 1–10000, and a profile has been made upon which essential information has been placed.

These are herewith submitted.

Very respectfully, your obedient servant,

W. M. REES,
Assistant Engineer.

Capt. S. W. ROESSLER,
Corps of Engineers, U. S. A.

The following table shows elevation of high-water mark during floods of 1882 and 1890, referred to Memphis datum:

Location.	1882.	1890.
Old Town Landing		189. 0
Modoc Landing		183. 7
Hughey Landing		182. 2
Offutt Landing		177. 5
Ludlow Landing	176. 8	175. 7
J. Ferguson's place		174. 3
Knowlton Landing	172. 0	172. 5
Laconia	169. 6	171. 6
Henrico	167. 5	170. 0

WHITE RIVER FRONT.

Table showing in detail the quantities in each section from Station 765 to 2,609.

Section.	Station from—	Station to—	Embankment (cubic yards). Enlargement.	Embankment (cubic yards). New work.	Muck ditch.	Timber felling.	
						Acres.	
....	765	884+64	181,841.6	....	5,310.6	....	Old levee, 11,964 feet.
....	884+64	914	....	46,100.0	1,761.6	....	
....	914	915	....	12,000.0	....	59.95	From 765 to 915.
18........	915	950+40	....	57,756.3	2,724.0	16.71	
19........	950+40	1,003+20	....	89,198.9	3,000.0	18.17	
20........	1,003+20	1,056	100,017.6	....	3,600.0	28.63	This section is 6,280 feet long. Old levee 31,680 feet.
21........	1,056	1,108+80	99,763.5	....	3,000.0	24.24	
22........	1,108+80	1,161+60	109,332.8	....	3,000.0	24.24	
23........	1,161+60	1,214+40	65,797.5	....	3,000.0	24.13	
24........	1,214+40	1,267+20	52,772.5	....	3,000.0	23.60	
25........	1,267+20	1,320	52,159.7	....	3,000.0	16.48	
26........	1,320	1,372+80	....	61,645.5	3,000.0	11.93	
27........	1,372+80	1,425+60	....	83,696.0	3,000.0	23.87	
28........	1,425+60	1,478+40	....	85,200.5	3,000.0	23.87	
29........	1,478+40	1,531+20	....	66,055.9	3,000.0	24.24	
30........	1,531+20	1,577	59,414.6	....	3,000.0	21.12	5,280 feet. Old levee 20,420 feet.
31........	1,577	1,629+80	44,943.5	....	3,000.0	21.12	
32........	1,629+80	1,682+60	35,771.2	....	3,000.0	24.24	
33........	1,682+60	1,735+40	48,992.1	....	3,000.0	24.24	
34........	1,735+40	1,788+20	....	59,978.8	3,000.0	24.24	
35........	1,788+20	1,841	....	67,807.4	3,000.0	23.87	
36........	1,841	1,893+80	....	84,441.4	3,000.0	24.24	
37........	1,893+80	1,946+60	....	117,589.6	3,000.0	24.24	
38........	1,946+60	1,999+40	....	91,362.2	3,000.0	24.24	
39........	1,999+40	2,052+20	....	78,818.3	3,000.0	23.87	
40........	2,052+20	2,105	....	52,179.8	3,000.0	18.52	
41........	2,105	2,157+80	....	55,191.0	3,000.0	10.56	
42........	2,157+80	2,234+60	....	44,773.2	3,000.0	18.34	
43........	2,234+60	2,287+40	....	74,158.0	3,000.0	24.24	
44........	2,287+40	2,406+20	85,916.6	....	3,000.0	24.24	5,280 feet in section. Old levee 17,160 feet.
45........	2,406+20	2,459	62,509.4	....	3,000.0	12.85	
46........	2,459	2,511+80	....	45,832.1	3,000.0	5.51	
47........	2,511+80	2,564+60	....	51,506.8	3,000.0	12.12	
48........	2,564+60	2,609	....	57,221.5	2,700.0	19.92	
Total			999,232.6	1,882,513.2	100,120.2	701.78	

Totals:	Cubic yards.
Enlargement	999,232.6
New work	1,382,513.2
Muck ditch	100,120.2
Total	2,481,866.0

Total old levee, used which has been deducted from above quantities, 468,210 cubic yards.
Length of old levee occupied, 81,224 feet=15.4 miles.

PLUM POINT REACH.

Table showing least channel depths and velocity of the river channels from May 31, 1890, to May 31, 1891.

Date.	Elmot gauge readings. (Zero equals 238.06, Cairo datum.)	Gold Dust.		Island No. 30.		Plum Point.		Osceola Bar to Dikes.	
		Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
1890.									
June 6	20.00	.....	.....	30	5.10	34	3.62	40	.....
13	13.00	.....	.....	22	5.03	27½	3.80	32	.....
20	15.00	.....	.....	25	5.38	28	4.08	39	.....
27	15.10	.....	.....	25	5.00	28	4.51	40	.....
July 21	8.50	.....	.....	18	4.62	21	3.97	30	.....
29	6.60	.....	.....	16	4.22	19½	3.83	28	.....
Aug. 6	5.50	.....	.....	15	4.19	19	4.55	27	.....
13	4.49	.....	.....	14	4.15	18	3.65	26	.....
20	4.90	.....	.....	14	4.22	18	3.67	26	.....
26	4.10	12½	3.94	12	4.37	17	3.43	25	.....
Sept. 8	6.60	.....	.....	15	4.15	19	3.58	24	.....
12	5.35	15	3.51	14	4.98	17½	.....	26	.....
Oct. 11	6.50	15	.....	17	.....	20	.....	28	.....
Nov. 20	10.10	18½	4.85	17	5.01	21	4.97	28	.....
26	14.85	22	4.47	24	5.91	24	4.57	34	.....
Dec. 5	7.87	16½	3.58	18	4.54	20	3.86	26	.....
12	4.95	14	3.20	15	4.31	18	3.81	25	.....
1891.									
Jan. 9	18.70	29	4.76	31	4.97	32	5.05	37½	.....
13	20.60	30½	4.86	32	6.05	35	3.74	40½	.....
20	18.10	27½	4.67	29½	4.92	32	3.82	38	.....
30	13.30	24	4.56	23	4.32	26	4.56	33	.....
Feb. 5	20.95	32½	.....	31½	.....	32½	.....	41	.....
11	25.70	36	5.33	34	6.30	38	4.76	44	.....
May 25	7.70	13	3.83	16½	4.59	18¼	4.76	24	3.89

Date.	Lower Plum Point.		Lynch's.		Bullerton Gap.		Bullerton.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
1890.								
June 6	30	4.20	24	4.20	23	4.29	11	2.60
13	24½	4.20	16	3.40	15	.....	3½	.....
20	26	4.44	20	4.26	17	3.36	5	.....
27	25	3.95	21	3.90	17	3.36	5	.....
July 21	19½	3.93	10	3.82	5½	.....	(*)	.....
29	17	4.55	6½	4.08	2½	.....	(*)	.....
Aug. 6	15	4.18	5	3.97	1	.....	(*)	.....
13	14	4.00	8	3.72	1	.....	(*)	.....
20	14½	4.00	8	3.06	3	.....	(*)	.....
26	13½	.....	8	2.75	3	.....	(*)	.....
Sept. 8	15	4.26	10	3.32	6½	.....	(*)	.....
12	14	3.95	9	3.18	5	.....	(*)	.....
Oct. 11	17	.....	10½	.....	6	.....	(*)	.....
Nov 20	17	3.81	14	3.09	12½	3.53	(*)	.....
26	23	3.79	19	4.39	16½	4.05	(*)	.....
Dec. 5	14	3.50	17	3.40	10	3.12	(*)	.....
12	12	3.61	8½	3.51	7	2.04	(*)	.....
1891.								
Jan. 9	27	4.27	21	5.07	20½	3.22	8	1.69
13	29	4.41	27	5.29	22½	4.05	10½	3.15
20	27½	3.53	23½	4.16	20	4.22	7½	2.97
30	21	4.35	18	4.02	14	2.70	.....	.....
Feb. 5	30	.....	26	.....	22½	.....	11	.....
11	34	4.35	30	4.82	26½	4.09	15	2.15
May 25	16	3.59	11	3.64	10	3.55	.....	.....

* No discharge.

Abstract of proposals for brush and poles for use at Columbus, Ky., received in response to advertisement dated July 23, 1890, and opened August 7, 1890, by Capt. S. W. Roessler, Corps of Engineers.

No.	Name and residence of bidder.	Brush.	Poles.
		Per cord.	*Per cord.*
1	Whitney Gilbreath, Ava, Ill	$1.18	$1.48
2	Julius Serbian, Cairo, Ill	1.48	2.24
3	Hunter & Frey, Memphis, Tenn	1.25	2.35
4	Holmes & Stockley, Memphis, Tenn	1.23	2.25
5	Bryant & Pickett, Hickman, Ky	1.05	1.50

NOTE.—Bid of Bryant & Pickett accepted.

Abstract of proposals for levee work in second district, received in response to advertisement dated November 8, 1890, and opened November 18, 1890, by Capt. S. W. Roessler, Corps of Engineers.

No.	Name and residence of bidder.	Upper Mississippi Levee district (per yard).						Helena Front (per yard.)	Laconia Circle (per yard).			
		Section 60.	Section 61.	Sections 65, 66, 67.	Hushpuckana Crossing.	Robertsonville Field.	Apperson's Field.		Buck Ridge to Big Henrico.	Big Henrico to Laconia.	Laconia to Desha County line.	Desha County line northward.
		Cts.	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*	*Cts.*
1	Harvey & Scott, Memphis, Tenn	*23	*24	21					*16	*17	*16	*19½
2	Z. A. Hakes, Memphis, Tenn										19½	
3	Flynn & De Garis, Memphis, Tenn			24½								
4	T. Sullivan, Memphis, Tenn	30	30	*19½	*35	*25	27					
5	A. Arnold & Co., Memphis, Tenn	26	28½	23¾				†31	21¾	24¾	22½	21
6	Cary Bros., New Orleans, La				39	29	28					
7	T. S. Aderholdt, Friar Point, Miss			22½		25	*24½					
8	Jos. C. Neeley, Bardwell, Ky										18¾	
9	P. F. Lamb, Memphis, Tenn								19½	22	22¾	24

*Accepted. †Rejected.

Abstract of proposals for levee work in second district, received in response to advertisement dated December 13, 1890, and opened December 19, 1890, by Capt. S. W. Roessler, Corps of Engineers.

No.	Name and residence of bidder.	Helena Front (per cubic yard).					
		Stations 765 to 804.66.	Stations 804.66 to 822.56.	Stations 822.56 to 857.35.	Stations 857.35 to 870.66.	Stations 870.66 to 884.64.	Stations 884.64 to 914.
		Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1	Jeffries & Dameron, Memphis, Tenn	28¾	28¾	28¾	28¾	28¾	28¾
2	Timothy Sullivan, Memphis, Tenn	27½	27½	27½	27½	27½	27½
3	Johnson & McDonell, Memphis, Tenn	24½	23½	31	23¾	29	23¾

NOTE.—All bids rejected.

Abstract of proposals for four mattress barges, received in response to advertisement dated May 5, 1891, and opened May 20, 1891, by Capt. S. W. Roessler, Corps of Engineers.

No.	Name and residence of bidder.	Cost.
1	David S. Barmore, Madison, Ind	$5,320 each for two mattress barges to be delivered on Plum Point Reach not later than July 20, 1891, provided navigation is not suspended on Ohio River. $4,920 each for two mattress barges to be delivered at Madison, Ind., not later than July 20, 1891. $5,220 each for four mattress barges to be delivered on Plum Point Reach not later than Aug. 10, 1891, provided navigation is not suspended on Ohio River. $4,900 each for four mattress barges to be delivered at Madison, Ind., not later than Aug. 10, 1891.

NOTE.—Bids rejected.

Abstract of proposals for brush and poles for use at Plum Point Reach, received in response to advertisement dated May 23, 1891, and opened June 13, 1891, by Capt. S. W. Roessler, Corps of Engineers.

No.	Name and residence of bidder.	Brush.	Poles.
		Per cord.	*Per cord.*
1	Joseph Evins, Dardanelle, Ark	$1.11	$2.25
2	Hunter & Frey, Memphis, Tenn	1.02	1.50
3	Driver & Carr, Osceola, Ark	1.09½	1.75

NOTE.—Bid of Hunter & Frey accepted.

IMPROVING MISSISSIPPI RIVER, FIRST AND SECOND DISTRICTS.

Itemized statement of expenditures on works of construction, from June 1, 1890, to May 31, 1891.

	Care and repairs of plant.	Surveys.	Fletcher Bend revetment.	Elmot Chute Dike.	Island 30 Chute Dike.
Coal	$863.15	$637.25	$61.80	$293.97	$129.09
Iron	496.03	1.50	30.67	4.15	
Lumber	4,695.98	4.48	22.93	27.79	
Nails	111.25		1.37	2.50	
Oakum	447.44		2.74	1.87	
Oils and supplies	253.30	56.82	15.98	28.58	28.04
Paint	1,030.10	5.90			
Pipe-fittings	258.68				
Rope	345.64	44.08		65.00	
Spikes	109.39		1.59	66.25	51.04
Towing	2,434.91		153.46	483.37	170.07
Piling	23.20			1,071.94	606.60
Wire and wire strand				474.54	223.35
Brush					
Poles					
Stone					
Miscellaneous	1,415.66	152.17	32.45	25.00	2.13
Superintendence and labor	43,099.89	5,421.52	1,873.52	3,539.86	2,032.53
Office and general administration	5,837.24	647.05	196.70	881.71	626.34
	61,421.89	6,970.77	2,393.21	6,966.53	3,869.79

Itemized statement of expenditures on works of construction, etc.—Continued.

	Columbus, Ky.	Osceola Bar.	Ashport Bend.	Hopefield Bend.	Total.
Coal	$1,380.50	$468.70		$618.75	$4,453.81
Iron	49.46	44.15		7.28	633.24
Lumber	378.45	42.80		22.50	5,194.93
Nails	22.81	8.62			146.55
Oakum	127.89	7.55			587.49
Oils and supplies	48.75	223.52			654.99
Paint					1,036.00
Pipe-fittings					258.68
Rope	114.50	1,851.90		358.62	2,779.74
Spikes	88.42	121.51		36.30	474.50
Towing	562.92	2,112.07		25.00	5,911.83
Piling					1,701.74
Wire and wire strand	1,087.77	2,749.10		878.24	5,413.00
Brush	1,934.10	12,402.17		1,995.55	16,331.82
Poles	636.00	2,928.41		399.63	3,964.04
Stone	3,178.23	17,482.68		2,264.00	22,924.91
Miscellaneous	82.56	19.18		52.97	1,782.12
Superintendence and labor	10,309.22	27,719.05	$114.00	7,161.75	101,271.34
Office and general administration	1,071.51	6,670.68	10.35	1,313.08	17,254.66
	21,073.09	74,852.09	124.35	15,133.67	192,805.39

Approximate value of plant belonging to the United States and used upon the improvement of the Mississippi River, first and second districts.

Class of property.	No.	Approximate value May 31, 1891.	Class of property.	No.	Approximate value May 31, 1891.
Steamer *Titan*	1	$20,523	Graders	2	$15,210
Steamer *Kirns*	1	8,742	Derrick boat	1	1,800
Steamer *Itasca*	1	6,513	Barges	43	22,936
Steamer *Graham*	1	6,360	Machine-shop boats	2	3,975
Steamer *Abbot*	1	3,000	Floating dock	1	6,110
Launch *Titania*	1	363	Flatboats	3	325
Launch *Daphne*	1	470	Skiffs	23	230
Pile drivers	36	42,134	Tools, appliances, etc		12,500
Quarter boats	17	22,366	Office furniture		264
Mattress barges	8	10,852	Surveying instruments		625
Mooring barges	6	5,045			
Sand pump	1	2,569	Total		192,912

FIRST AND SECOND DISTRICTS.

Disbursements made under appropriation for improving Mississippi River from July 1, 1890, to June 30, 1891.

Contracts made with—	For what made.	Disbursements under contracts.	Liabilities under contracts.	Total.
Bryant & Pickett	Willow brush and poles	$2,645.48		$2,645.48
Harvey & Scott	Levee work	81,862.27	$61,332.31	81,862.27
Timothy Sullivan	...do	25,362.58		86,694.89
T. S. Allerholdt	...do	5,252.31		5,252.31
		115,122.64	61,332.31	176,454.95

Disbursements made otherwise than under contract.

For what expended.	By public notice and sealed proposals.	In open market.	Liabilities.	Total.
Material and supplies	$14, 915. 71	$47, 695. 03	$31, 219. 69	$93, 830. 43
Subsistence	10, 294. 36	13. 752. 88	964. 81	25, 012. 05
Services		123, 235. 67	6, 450. 00	129, 685. 67
Tools, appliances, and outfit	200. 14	8, 455. 17	6, 295. 18	14, 950. 49
Miscellaneous	40. 75	4, 228. 65	104. 14	4, 373. 54
	25, 450. 96	197, 367. 40	45, 033. 82	267, 852. 18

List of civilian engineers employed on work of improving Mississippi River, first and second districts, in charge of Capt. S. W. Roessler, Corps of Engineers, from June 1, 1890, to May 31, 1891.

Name and residence.	Time employed.	Pay per month.	Where employed.	Work on which employed.
	Months.			
Aug. J. Nolty, Chattanooga, Tenn.	5	$150	Amelia, Ark	Improving Mississippi River: Plum Point Reach.
	7	175	....do	Do.
W. M. Rees, Memphis, Tenn	$2\frac{11}{30}$	200	Memphis, Tenn	Levees, White River Basin and office duties.
	$3\frac{13}{30}$	175	....do	Do.
	$\frac{6}{30}$	200	... do	Appropriation for examinations, surveys and contingencies of rivers and harbors (act of September 19, 1890.
C. W. Sturtevant, Amelia, Ark.	$4\frac{28}{30}$	120	Amelia, Ark	Improving Mississippi River; surveys, first and second districts.
	$7\frac{4}{30}$	150	....do	Improving Mississippi River; Memphis Reach and Columbus, Ky.
Wm. Gerig, Columbia, Mo	$2\frac{5}{30}$	125	Modoc, Ark	Improving Mississippi River; levees, White River Basin.
	3	125	Memphis, Tenn	Improving Mississippi River; surveys, first and second districts.
Charles W. Stewart, Champaign, Ill.	$4\frac{21}{30}$	140	Columbus, Ky	Improving Mississippi River; Columbus, Ky.
Louis E. Ritter, Cleveland, Ohio.	$6\frac{4}{30}$	125	Amelia, Ark	Improving Mississippi River; surveys, first district.
Gustav Bischoff, Memphis, Tenn.	$\frac{26\frac{1}{2}}{30}$	90	Memphis, Tenn	Improving Mississippi River; survey of St. Francis Front.
S. E. Moore, Friar Point, Miss.	$\frac{18}{30}$	150	Friar Point, Miss	Improving Mississippi River; levees, Upper Mississippi levee district.
	$6\frac{28}{30}$	175	....do	Do.
Fred. Wigstrand, Friar Point, Miss.	8	100	....do	Do.
E. T. Washburn, Friar Point, Miss.	$2\frac{28}{30}$	100	....do	Do.
E. C. Tollinger, Arkansas, City, Ark.	2	175	Laconia, Ark	Improving Mississippi River; levee, White River Basin.
Hy. Steubing, Louisville, Ky.	$4\frac{11}{30}$	150	....do	Do.
Henry Goodrich, Lake Providence, La.	$\frac{18}{30}$	140	....do	Do.
A. F. Kilpatrick, Memphis, Tenn.	$6\frac{11}{30}$	125	....do	Do.
B. Dornblaser, Memphis, Tenn.	$\frac{18}{30}$	100	....do	Do.
T. N. Llewellyn, Arkansas, City, Ark.	$2\frac{27}{30}$	100	....do	Do.
George R. Lacy, Arkansas, City, Ark.	$\frac{13}{30}$	75	....do	Do.
	$4\frac{17}{30}$	90	....do	Do.
D. H. Howell, Arkansas City, Ark.	$1\frac{28}{30}$	75	....do	Do.
John C. Hutchinson, Arkansas City, Ark.	1	70	....do	Do.

River tonnage and passenger traffic for the calendar year 1890.

Name of line or steamer.	Description.		No. of trips.	Total freight.	Greatest draft.		Average tonnage.	Passengers carried.	
	Steamers.	Barges.						Cabin.	Deck.
				Tons.	*Ft.*	*in.*			
Memphis and Cincinnati Packet Company	7	....	86	14,633	9	0	795	....	....
St. Louis and Mississippi Valley Transportation Company	10	....	68	....	....		....	....	....
	....	85	408	450,682	....		1,400	....	....
St. Louis and New Orleans Anchor Line	3	....	46	110,694	9	0	2,000	4,504	3,190
St. Louis and Natchez Anchor Line	7	....	128	149,934	9	8	1,500	21,162	19,595
Steamer *State of Missouri*	1	....	1	2,400	6	6	2,000	....	....
Steamer *U. P. Schenck*	1	....	9	14,169	....		1,178	565	....
Lee Line steamers	5	....	....	61,000	....		530	....	....
Steamer *New Mary Houston*	1	....	....	18,169	....		1,164	1,164	....
Steamer *Chickasaw*	1	....	....	13,792	....		734	2,331	....
Arkansas River Packet Company	2	....	55	17,682	....		548	....	....
Steamer *Guiding Star*	1	....	8	14,361	....		1,122	1,912	994
Steamer *Kate Adams*	1	....	104	27,029	9	0	1,200	4,040	12,120

NOTE.—It has been impossible to obtain satisfactory lists giving the amounts of the principal articles transported, as such classifications have not heretofore been kept by all the steamboat lines.

Appropriations for improving Mississippi River, first and second districts.

June 30, 1890. Balance available, as follows:		
First district	$66,548.85	
Second district	28,643.78	
First and second districts	19,002.37	
		$114,195.00
June 30, 1891. Amount allotted by Mississippi River Commission to date, as follows:		
Plum Point Reach	747,500.00	
Plant, first and second districts	130,500.00	
Levees, Upper Mississippi levee district	90,000.00	
Levees, second district, Yazoo Front	15,250.00	
Levees, White River Basin	192,500.00	
Preservation of works	15,000.00	
Surveys, gauges, and observations	15,000.00	
Hickman, Ky	500.00	
New Madrid, Mo	1,000.00	
Helena, Ark	22,500.00	
		1,229,750.00
Total		1,343,945.00
July 18, 1890. Amount reserved by Chief of Engineers (Hickman, Ky.)	$118.00	
March 21, 1891. Amount reallotted by Mississippi River Commission	125,000.00	
June 30, 1891. Amount expended from July 1, 1890, to date, exclusive of liabilities outstanding June 30, 1890	330,931.07	
Outstanding liabilities	45,033.82	
Amount covered by existing contracts	61,332.31	
		562,415.2
June 30, 1891, balance available		781,529.8
Amount that can be profitably expended in fiscal year ending June 30, 1893		1,000,000.

Submitted in compliance with requirements of sections 2 of the river and harbor acts of 1866 and 1867.

APPROPRIATION FOR IMPROVING MISSISSIPPI RIVER, FIRST AND SECOND DISTRICTS.

General balance sheet.

PLUM POINT REACH.

1890. June 30	To balance, including liabilities	$12,165.22	1891. Mar. 21	By amount reallotted by Mississippi River Commission	$125,000.00
Nov. 25	To amount allotted by Mississippi River Commission	297,500.00	June 30	By amount expended from July 1, 1890, to date	103,639.44
1891. Mar. 30	......do	450,000.00		By liabilities	26,131.15
				By balance	504,894.63
		759,665.22			759,665.22

LEVEES, PLUM POINT REACH.

1890. June 30	To balance	$75.97	1890. Dec. 31	By amount transferred to preservation of works	$75.97

SURVEY OF ST. FRANCIS FRONT.

1890. Oct. 2	To amount transferred from protection of levees, second district	$300.00	1890. Dec. 31	By amount expended	$249.50
				By amount transferred to surveys, gauges, and observations	50.50
		300.00			300.00

GAUGES, FIRST DISTRICT.

1890. June 30	To balance, including liabilities	$931.50	1890. Dec. 31	By amount expended	$368.00
				By amount transferred to surveys, gauges, and observations	563.50
		931.50			931.50

SURVEYS AND EXAMINATIONS, FIRST DISTRICT.

1890. June 30	To balance	$1,841.45	1890. Dec. 31	By amount expended	$632.97
				By amount transferred to surveys, gauges, and observations	1,208.48
		1,841.45			1,841.45

HICKMAN, KENTUCKY.

1890. June 30	To balance	$48,647.76	1891. June 30	By amount expended	$1,659.34
Nov. 25	To amount allotted by Mississippi River Commission	500.00	1890. July 18	By amount reserved by Chief of Engineers	118.00
			1891. June 30	By balance	47,370.42
		49,147.76			49,147.76

General balance sheet—Continued.

COLUMBUS, KENTUCKY.

1890. June 30	To balance, including liabilities	$13,016.16	1890. Dec. 31	By amounted expended to date	$13,016.16

NEW MADRID, MISSOURI.

1890. Nov. 25	To amount allotted by Mississippi River Commission	$1,000.00	1891. June 30	By balance	$1,000.00

MEMPHIS REACH.

1890. June 30	To balance, including liabilities	$16,178.67	1890. Dec. 31	By amount expended	$12,780.70
				By amount transferred to Memphis Harbor	3,397.97
		16,178.67			16,178.67

MEMPHIS HARBOR.

1890. June 30	To balance, including liabilities	$5,619.74	1891. June 30	By amount expended to date	$6,103.28
Dec. 31	To amount transferred from Memphis Reach	3,397.97		By liabilities	29.35
				By balance	2,885.08
		9,017.71			9,017.71

LEVEES, WHITE RIVER FRONT.

1890. June 30	To balance	$3,954.35	1890. Dec. 31	By amount expended	$662.47
				By amount transferred to levees, White River Basin	3,291.88
		3,954.35			3,954.35

FIRST LEVEE DISTRICT, MISSISSIPPI.

1890. June 30	To balance	$510.06	1890. Dec. 31	By amount transferred to levees, Upper Mississippi levee district	$510.06

OBSERVATIONS AND DISCHARGES, SECOND DISTRICT.

1890. June 30	To balance	$2.07	1890. Dec. 31	By amount expended	$2.07

General balance sheet—Continued.

GAUGES, SECOND DISTRICT.

1890. June 30	To balance, including liabilities	$282.50	1890. Dec. 31	By amount expended	$270.00
				By amount transferred to surveys, gauges, and observations	12.50
		282.50			282.50

SURVEYS AND EXAMINATIONS, SECOND DISTRICT.

1890. June 30	To balance	$1,575.06	1890. Dec. 31	By amount expended	$455.17
				By amount transferred to surveys, gauges, and observations	1,119.89
		1,575.06			1,575.06

HELENA, ARK.

1890. June 30	To balance	$2.80	1891. June 30	By balance	$22,502.80
Oct. 15	To amount allotted by Mississippi River Commission	22,500.00			
		22,502.80			22,502.80

PROTECTION OF LEVEES, SECOND DISTRICT.

1890. June 30	To balance	$5,904.45	1890. Oct. 2	By amount transferred to survey St. Francis Front	$300.00
			Dec. 31	By amount transferred to preservation of works	5,604.45
		5,904.45			5,904.45

CARE OF PLANT, FIRST AND SECOND DISTRICTS.

1890. June 30	To balance, including liabilities	$20,452.15	1890. Dec. 31	By amount expended	$20,444.80
				By amount transferred to plant, first and second districts	7.35
		20,452.15			20,452.15

SURVEYS, FIRST AND SECOND DISTRICTS.

1890. June 30	To balance	$1,255.30	1890. Dec. 31	By amount expended	$731.14
				By amount transferred to surveys, gauges, and observations	524.16
		1,255.30			1,255.30

General balance sheet—Continued.

PLANT, FIRST AND SECOND DISTRICTS.

1890. Nov. 25	To amount allotted by Mississippi River Commission	$130,500.00	1891. June 30	By amount expended to date.	$35,406.29
				By liabilities	18,418.32
				By balance	76,682.74
Dec. 31	To amount transferred from care of plant	7.35			
		130,507.35			130,507.35

PRESERVATION OF WORKS, FIRST AND SECOND DISTRICTS.

1890. Nov. 25	To amount allotted by Mississippi River Commission	$15,000.00	1891. June 30	By amount expended to date.	$2,163.90
				By balance	18,516.52
Dec. 31	To amounts transferred as follows:				
	Protection of levees, Second district	5,604.45			
	Levees, Plum Point Reach	75.97			
		20,680.42			20,680.42

SURVEYS, GAUGES, AND OBSERVATIONS.

1890. Nov. 25	To amount allotted by Mississippi River Commission	$15,000.00	1891. June 30	By amount expended to date	$5,314.94
				Liabilities	455.00
				Balance	12,709.09
Dec. 31	To amounts transferred, as follows:				
	Surveys and examinations First district	1,208.48			
	Surveys and examinations Second district	1,119.89			
	Gauges, First district	563.50			
	Gauges, Second district	12.50			
	Surveys, first and second districts	524.16			
	Surveys, St. Francis Front	50.50			
		18,479.03			18,479.03

LEVEES, UPPER MISSISSIPPI RIVER LEVEE DISTRICT.

1890. Nov. 25	To amount allotted by Mississippi River Commission	$90,000.00	1891. June 30	By amount expended to date	$55,543.92
				By liabilities	34,966.16
Dec. 31	To amount transferred from First levee district, Mississippi	510.08			
		90,510.08			90,510.08

LEVEES, SECOND DISTRICT, YAZOO FRONT.

1891. Mar. 19	To amount allotted by Mississippi River Commission	$15,250.00	1891. June 30	By amount expended to date	$1,505.
				By balance	13,744.
		15,250.00			15,250

General balance sheet—Continued.

LEVEES, WHITE RIVER BASIN.

1890. Nov. 25	To amount allotted by Mississippi River Commission	$180,000.00	1891. June 30	By amount expended to date	$76,925.73
				By liabilities	26,366.15
Dec. 31	To amount transferred from levees, White River Front	3,291.88		By balance	92,500.00
1891. Mar. 19	To amount allotted by Mississippi River Commission	12,500.00			
		195,791.88			195,791.88

Appropriation for examinations, surveys, and contingencies of rivers and harbors (act September 19, 1890).

PRELIMINARY EXAMINATIONS.

1890. Sept. 20	To amount allotted by Chief of Engineers	$100.00	1891. June 30	By amount expended to date.	$66.00
				By balance	34.00
		100.00			100.00

APPENDIX E.

REPORT OF CAPTAIN C. McD. TOWNSEND, CORPS OF ENGINEERS, UPON OPERATIONS IN THE THIRD DISTRICT.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., June 30, 1891.

GENERAL: I have the honor to submit the following report of operations in the third district, improving the Mississippi River, for the fiscal year ending June 30, 1891.

Per Special Orders, No. 141, Headquarters of the Army, Adjutant-General's Office, Washington, D. C., June 17, 1890, I relieved Capt. Willard Young, Corps of Engineers, of the charge of the district.

Capt. S. W. Roessler, Corps of Engineers, was temporarily in charge from August 28, 1890, to March 9, 1891, per Special Orders 55, Corps of Engineers, Washington, D. C., August 28, 1890.

The third district extends from the mouth of the White River to Warrenton, Miss., a distance of 220 miles. In its improvement work has been undertaken at Lake Providence Reach, Vicksburg Harbor, Delta Point, Greenville, Ashbrook Neck, and Lake Bolivar Front. Levees have been constructed and enlarged in the Lower Mississippi levee district, Tensas Front, Arkansas, and Louisiana.

During the last fiscal year operations have been confined to Vicksburg Harbor, Ashbrook Neck, the construction and high-water protection of levees, care and repair of plant, and surveying and gauging the river.

LAKE PROVIDENCE REACH.

This reach extends from Carolina Landing, Miss., 517 miles from Cairo, to the foot f Island 95, a distance of 35 miles. Before the improvement was undertaken, a epth of but 4½ feet, at low water, was reported on some of the crossings. (Report f Mississippi River Commission, 1883, page 408.)

The works of improvement have consisted in building permeable dikes for closing hutes, and contracting wide portions of the river, and revetment of banks, to preent caving. Dikes have been constructed at Duncansby Crossing, Cottonwood, ayersville, Elton, Baleshed, and Stack Island, and are fully described in previous ports of the Commission.

The immediate effect of these dikes was very beneficial. A deposit of from 6 to 18 et was made behind them the first season, chutes were closed, and the river at low

water contracted. The least depth that has been recorded on crossings in Lake Providence Reach since their construction has been 7 feet.

The extensive caving of the banks, however, which has extended from Louisiana Bend down through this reach, has successively flanked and destroyed these dikes, until the Baleshed and Stack Island systems alone remain, and the river now threatens to destroy the upper portion of the Baleshed.

Revetment, or bank protection, has been undertaken at Mayersville Island and at Louisiana Bend. Mayersville Island was flanked and washed away; the revetment disappeared with the island. The first revetment placed in Louisiana Bend suffered the same fate, but that constructed there in 1889, 6,024 feet in length, has successfully withstood the action of two freshets.

A summary of the condition of this reach is given in the accompanying report of United States Surveyor William P. Richards.

The revetment of Louisiana Bend will be extended during present low-water season, as far as the available plant will admit.

Attention is invited to the increased caving that is taking place above Lake Providence, La., which, unless checked, will eventually extend to the town, and by breaking into the lake necessitate a very extensive and costly change in the position of levees in that locality.

From the records of the board of State engineers of Louisiana, furnished through the courtesy of Assistant State Engineer, H. B. Thompson, of Louisiana, I find that caving from 1866 to 1882 in this locality was at the rate of about 100 feet per year, from 1882 to 1890, at the rate of about 262 feet per year, and from 1890 to 1891, from 600 to 800 feet. The destruction of the Baleshed system of dikes may be expected to accelerate the caving in front of the town.

VICKSBURG HARBOR AND DELTA POINT.

The holding of Delta Point has been an essential part of all projects for improving Vicksburg Harbor. The revetment of its caving banks was commenced in 1878, and continued until 1884, 10,700 linear feet being thus protected. Since that date some repairs have been made, but none have been required during the last two years. The bank is caving extensively above the portion protected, and it will be necessary ultimately to extend the revetment farther up the river to prevent the flanking and destruction of the work already constructed. This work should, however, be deferred until the caving has assumed a more uniform surface.

The project for the improvement of Vicksburg Harbor, under which work is being carried on, was approved by the Secretary of War in 1887, and is as follows:

To prevent the water flowing into Centennial Lake and make a still-water basin in front of the city; then to dredge a navigable basin in this basin, and a canal connecting it with the river. To carry out this project it was proposed to build a dam across the lake from the city to De Soto Island, and a dike from near the river end of the island to the canal, thence parallel to the canal to the river. The basin was to be 1,700 feet long and 300 feet wide; the canal 75 feet wide at the bottom, with a slope of 1 on 3 on the land side, and 1 on 5 on the water side.

The material dredged has been deposited along this dike and dam, with the intention of ultimately surrounding the basin with a dam of earth.

To the beginning of the present year there had been excavated in the canal and basin 581,609 cubic yards under this project.

Dredging was then in progress, and in August, when work was suspended on account of the low stage of the river, the canal had been excavated to the plane +8 feet on the Vicksburg gauge, but the side slopes were left nearly vertical and commenced sliding into the canal, so that a navigable depth to the +8-foot plane was not attained.

Bids were opened for dredging Vicksburg Harbor January 11, 1891.

The following were received:

No.	Name of bidder.	Per cubic yard, scow measure.
		Cents.
1	B. L. Wood, jr	$14\frac{4}{5}$
2	Alabama Dredging and Jetty Company	*$13\frac{9}{10}$

* Contract was made for 11.9 cents for short haul.

The contract was awarded to the Alabama Dredging and Jetty Company, the lowest bidders, for 11.9 cents short haul and 13.9 cents long haul. Work was begun under this contract March 4, 1891, and by June 1, 1891, 164,000 cubic yards had been excavated.

The following extracts from the report of Assistant Engineer H. St. L. Coppée, who has been in local charge of the dredging, gives a detailed account of the work done. It should be noted that the estimates of material to be dredged, submitted by him, are computed for a width of canal of 100 feet, while the project calls for a canal of a bottom width of 75 feet. For a 75-foot canal the estimate would be to —5-foot plane, 1,064,598 cubic yards in place; to —10-foot plane, 1,552,488 cubic yards in place.

EXTRACT FROM REPORT OF ASSISTANT ENGINEER H. ST. L. COPPÉE.

At the time the last annual report was submitted three dredges were in operation in the harbor, two being contractor's dredges, and one the Government dredge *Menge*.

The contract work was being done by the Alabama Dredging and Jetty Company. The price paid 10 and 12 cents per cubic yard, measured in scows; the latter price being for long haul around De Soto Island to north side of dike. The amount available for the contract dredging at the commencement of that season's work was $50,000—$29,000 of the full allotment (of $79,000) being retained for changing, repairing, and operating the Government dredge *Menge* and outfit. The horizontal plane to which the dredging was being carried was +8 feet on the gauge. The base of proposed excavation being 100 feet wide, slopes on bar side 5 to 1, and on city side, 3 to 1.

Up to May 1, 1890, the two contractor dredges had moved material from canal as follows:

	Long haul.	Short haul.	Total.
	Cubic yards.	*Cubic yards.*	*Cubic yards.*
Dredge Herndon	47,002	14,762	61,764
Dredge Shelly	63,890	83,032	146,922
Total	110,892	97,794	208,686

By a glance at the accompanying hydrograph for 1890 (omitted), it will be seen that during the time the dredges were at work, up to May 1, the water had been at a high stage, and did not fall to an easy dredging plane until the middle of June, but from the latter date it fell very rapidly. Both the dredges used by the contractor were clam-shell diggers, of 4-yard-bucket capacity. The *Shelly* was worked day and night, and the *Herndon* only during daylight. A detailed description of these dredges is given in former reports.

In 1888 an appropriation was made for the improvement of the harbor, of $150,000; of this $15,000 was reserved for repairs to Delta Point, Louisiana. Captain Young, seeing the importance of continuing the dredging as long as possible and retaining the contractor's plant till another appropriation was made, requested of General Comstock, president of the Mississippi River Commission authority to use this reserve fund ($15,000) in dredging, but the General refused to comply with his request.

June 23, when I had arranged the work between the two dredges so as to facilitate finishing to the required plane (+8) before the water fell sufficiently to stop it, the *Shelly* was ordered away by the contractor; she was towed out of the harbor June 25, leaving the work in a very unsatisfactory condition.

My plans had to be changed and the *Herndon* placed in such a manner as to insure, if possible, a channel (of sufficient width to allow boats to pass) to the required depth before the water receded sufficiently to stop the work for that season.

No slopes were cut, but the dredge worked in the main channel cutting to +8 feet on the gauge, leaving vertical sides, there being no time for slope cutting.

June 25, the contractor asked for an extension of his contract, which was granted by the Chief of Engineers.

July 26, the river having reached the 16-foot stage with a constant downward tendency, the *Herndon* was withdrawn from the canal. The cutting at the mouth of the canal had proven a very slow and difficult job because of the great amount of sand that constituted the material dredged.

Owing to the withdrawal of the *Shelly* and the rapid decline of the river, some lumps were left in the canal that we contemplated removing.

At all stages above 14 feet on the gauge the smallest boats were able to use the canal, so that up to the end of 1890 there were but 2½ months that these boats were kept from the harbor.

The material moved by these contract dredges during the season's work, ending July 26, 1890, was as follows:

	Herndon.		Shelly.	
	Long haul.	Short haul.	Long haul.	Short haul.
	Cubic yards.	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*
February	....	....	6,609	8,365
March	....	....	34,223	39,792
April	47,002	14,762	23,058	34,875
May	43,841	18,988	31,659	46,587
June	6,999	42,526	14,564	13,760
July	....	29,171	....	....
Total	97,842	105,447	110,113	143,379

Total long haul	207,955 yards, at 12 cents	$24,954.60
Total short haul	248,826 yards, at 10 cents	24,882.60
Total	456,781	49,837.20

The canal, when the contract was finished, was cut to about the +8-foot plane. It was less than 100 feet wide at bottom in places and with much steeper slopes than 5 and 3 to 1. Consequently, during the lower stages of water, there was some sliding at the sides, which would not occur were the slopes cut to the proposed angles.

At the time of the making of the last annual report the *Menge* dredge was temporarily stopped for repairs and additions, patent roller track, steam capstan, etc., that were recorded in that report. Up to the time of making these changes and repairs, the work of the dredge had been very unsatisfactory, only making an average of 130 cubic yards per day. After the changes, the average yardage was increased to 350 per day, her best work being 740 yards in 10 hours.

The approximate cost of running the dredge was $65 per day, making the cost per yard, 18 cents. The stage of water during the most of the time this dredge was in operation was very unfavorable for working her. The output would have been considerably greater in lower water. This dredge was worked up to June 1, in the canal, and then had to be moved to the basin, where the material was so hard on the slope that she broke her cutter wheel, and was laid up permanently after operating until June 6. The material moved by this dredge during the season was as follows:

	Cubic yards.
March	792
April	722
May	6,195
June	1,083
Total	8,792

The total material moved during the season from the canal was:

	Yards in scows.
By *Menge* dredge	8,792
By contract dredges	456,781
Total	465,573

The first cost of the *Menge* and outfit was	$20,237.65
The season's work, repairs and additions	13,119.73
Total	33,357.38

At the close of the dredging season the canal was thoroughly cross sectioned, and the following estimate of material dredged (measured in place) submitted.

This estimate also gives a comparison of material moved in scows and in place, and the material to be moved at that time in order to finish the project, or to the planes from +6 down to 10 feet below zero.

If the river should reach its lowest recorded stage of 4 feet below zero, the channel depth would be (if the dredging was carried to the −10-foot plane) +6 feet, sufficient for all boats in this trade at that season of the year.

Material dredged in 1890.

[Excavation in canal by contractors and Government.]

Range.	Area.	Mean area.	District.	Cubic feet.	Cubic yards.
0	794.1	....	....	....	....
1	1,960.4	1,377.3	100	137,730	5,101.3
2	1,837.7	1,899.1	100	189,910	7,033.7
3	1,794.5	1,816.1	100	181,610	6,726.3
4	1,761.5	1,778.0	100	177,800	6,585.2
5	1,896.3	1,829.0	100	192,900	7,144.4
6	1,713.5	1,805.0	100	180,500	6,685.2
7	1,819.0	1,766.3	100	176,630	6,541.9
8	1,796.0	1,807.5	100	180,750	6,694.4
9	1,821.3	1,808.7	100	180,870	6,698.9
10	1,826.0	1,823.7	100	182,370	6,754.4
11	2,018.0	1,922.0	100	192,200	7,118.5
12	1,983.5	2,000.8	100	200,080	7,410.3
13	2,085.0	2,034.3	100	203,430	7,534.4
14	1,810.4	1,947.7	100	194,770	7,213.7
15	1,790.0	1,800.2	100	180,020	6,667.4
16	1,878.5	1,834.3	100	183.430	6,793.7
17	1,947.4	1,912.9	100	191,290	7,084.8
18	2,030.0	1,988.7	100	198,870	7,365.6
19	1,997.5	2,013.8	100	201,380	7,458.5
20	2,226.7	2,112.1	100	211,210	7,822.6
21	1,900.0	2,063.4	100	206,340	7,642.2
22	2,058.2	1,979.1	100	197,910	7,330.0
23	2,088.7	2,073.5	100	207,350	7,679.6
24	2,150.6	2,119.6	100	211,960	7,850.3
25	2,096.0	2,123.3	100	212,330	7.864.1
26	2,354.0	2,225.0	100	222,500	8,240.7
27	2,273.0	2,313.5	100	231,350	8,569.6
28	2,051.3	2,112.1	100	211,210	7,822.5
29	1,926.7	1,989.1	100	198,910	7,367.0
30	1,980.4	1,953.6	100	195,360	7,235.6
31	1.921.0	1.950.7	100	195,070	7,224.8
32	1,791.5	1,856.3	100	185,630	6,875.1
33	1,975.2	1,883.4	100	188,340	6,975.5
34	1.884.0	1,929.6	100	192,960	7,146.7
35	1,750.0	1,817.0	100	181,700	6,729.6
D	1,823.0	1,786.5	70	123,055	4,557.5
36	1,639.0	1,731.1	30	51,933	1,923.4
37	1,737.0	1,688.2	100	168,820	6,252.5
38	1,758.7	1,747.8	100	174,780	6,473.3
39	1,732.7	1,745.6	100	174,560	6,465.2
40	1,525.6	1,629.1	100	162,910	6,033.7
41	1,687.8	1,606.7	100	160,670	5,950.7
42	1,558.3	1,623.1	100	162,310	6,011.4
43	1,538.5	1,548.4	100	154,340	5,734.8
44	1,792.5	1,665.5	100	166,550	6,168.5
45	1,979.6	1,881.0	100	188,100	6,966.6
46	1,903.0	1,939.8	100	193,980	7,184.4
47	2,127.5	2,015.2	100	201,520	7,463.6
48	2,176.0	2,151.3	100	215,130	7,967.8
49	2,043.0	2,109.5	100	210,950	7,814.1
50	1,844.3	1,943.6	100	194,360	7,198.5
51	1,883.7	1,864.0	100	186,400	6,903.7
52	2,097.0	1,990.4	100	199,040	7,371.8
53	2,049.0	2,073.0	100	207,300	7,677.8
54	1,960.8	2,004.9	100	200,490	7,425.6
55	2,151.0	2,055.4	100	205,540	7,612.5
56	1,593.5	1,872.2	100	187,220	6,934.0
57	613.5	1,103.5	100	110,350	4,087.0
58	253.5	433.5	100	43,350	1,605.6
59	200.0	226.8	100	22,680	840.0
Total	....	....	....	10,843,530	401,610.7

	Cubic yards.
Material moved from canal	401,610.7
Ditch cut by *Menge* dredge in basin	966.0
Total	402,576.7

The material moved as excavated and measured in scows equal 465,573 cubic yards, which shows an expansion of between 15 and 16 per cent.

The following is the amount of material measured in place, as estimated after the

dredging season of 1890, that it would be necessary to move in order to cut the canal and basin to the + 6, + 5, + 4, + 3, + 2, + 1, 0, — 5, and — 10 foot planes:

	Cubic yards.
+6-foot plane canal and basin	257,967
+5-foot plane canal and basin	— 329,992
+4-foot plane canal and basin	— 404,441
+3-foot plane canal and basin	— 481,399
+2-foot plane canal and basin	— 560,781
+1-foot plane canal and basin	— 642,615
0-foot plane canal and basin	— 729,280
—5-foot plane canal and basin	—1,199,023
—10-foot plane canal and basin	—1,715,412

In order to obtain the plane to which it is possible to cut the canal and basin when the measurement is in scows, it is necessary to add 16 per cent. for expansion of material, before multiplying by contractor's price.

During the year 1890, the small boats were able to use the river harbor at all stages above 15 feet on the gauge, or all the year with the exception of 90 days, or say, 3 months.

The larger boats, Anchor Line, etc., owing to the presence of the lumps at upper end of canal, did not use it except at higher stages. The washing and sliding off of slopes in the canal, heretofore mentioned, was entirely due to the fact that the sides were cut so nearly perpendicular. The material slid from the sides, causing some little fall in the middle of the canal.

The floating property on hand when the work of 1890 was in operation was as follows:

Contractors plant: 1 dredge, *Shelly;* 1 dredge, *Herndon;* 4 large scows (about 475 yards each), 2 tugs, and 4 small boats.

Government plant: 1 dredge, *Menge;* 1 tug, *Parker;* 2 scows (about 200 yards each), 1 quarter boat, 1 barge, 1 pile driver, 2 calking flats, 4 skiffs, and 1 yawl.

As before stated, June 25 the dredge *Shelly*, with tug and 2 scows, left the harbor, and the remainder of the contractors' property followed July 28. The pile driver and barge were sent to Greenville during the high water.

August 4 the tug *Parker*, with the two dump scows, were sent to Memphis to be used in dredging in that harbor. In the mean time the dredge *Menge* and outfit was laid up and being cared for by watchmen employed for that purpose.

December 8 the remaining property, the dredge *Menge* and outfit, was turned over to Captain Kingman to be used at the mouth of Red River, Louisiana, where the conditions are much more favorable for working that kind of dredge.

Early in August, 1890, in accordance with instructions from you, I made a reconnoissance of the harbor and Delta Point, and the Mississippi River in the vicinity, with the assistance of an instrument-man and three laborers. I established four of the original triangulation stations, ran a meander line along Delta Point to a point directly opposite the mouth of the Yazoo River; also from a point on the Mississippi side of Kings Bar to the Refuge Oil Mill, connecting the latter line with the survey of the canal. In addition, soundings were made to show subaqueous slopes along these lines, and in order to define the low-water contours as nearly as possible.

August 15 a report and map were sent to your office, the result of the survey. The lines established are shown on the accompanying plate No. 12 (omitted) and the following extract is made from that report:

"A study of the map will show that no radical change has taken place in the river in this vicinity in the last 4 years. The change seems rather to have been gradual and in the same direction since 1882. The bar above Delta Point caved at the upper end 110 feet, approximately, back from the line of 1886, midway of the bar or opposite triangulation station (A).

The change was 200 feet at the lower end. Off point of old levee it increased to 350 feet.

Six hundred feet below this point, or where the bar originally and still ends, there exists a buckshot point, which has resisted the action of a very swift current for the last 6 years; from this buckshot point to just above the Delta wharf boat the subaqueous bank was in 1878 and 1879 covered with small 50 by 150 feet mattresses that have been swept away by the action of this current. As shown by the lines on the map from the point of this bar to the head of the revetted bank, the sloughing or caving is very extensive and destructive. The line of the top of the sliding bank in some places being as far as 250 feet back of the water, the buckshot point at the head of this reach is breaking up in vertical cleavage and sinking away from the main bank. A bad cave at the lower end against the head of the revetment threatens the stability of that work. On the Mississippi side, above the A. and V. incline, both the 15 foot and 0 planes of the present bank have moved out or built

up considerably since 1886, except in one small reach where the 0 line of 1886 is 450 feet outside.

From West Pass up the river for a distance of over a mile the +13-foot line of the year 1890 has moved out 400 feet from the line of 1886. From West Pass south, or down the river to the A. and V. incline, the change has been from 200 to 400 feet.

Below the incline to where the rock has been exposed, checking the erosion, the bank has caved on an average of 100 feet.

On the Louisiana side below the V. S. and P. incline the low-water line, as shown on map, is an approximation, no meander having been made or sounding taken to define it accurately.

The information derived from this reconnoissance points to the fact, as before mentioned, that no radical change had taken place in the regimen of the river here, but that there has been simply a continuation of the action that has existed in this vicinity for the last 6 or 8 years, to wit: The wearing away of the bank and bar above Delta Point towards its original position before the bar was made, the resulting breaking up of the exposed points below, bringing the bend to a more uniform and concave condition, but also threatening the destruction of railroad property at Delta Point and the flanking of the revetted bank now intact (1890); on the Mississippi side, the continued building of the bar from the West Pass up the river, and the caving of the bank south to where the exposed bluff rock has checked the force of the current.

The crest of the bar from the new canal northwest is very high, no water but that nearly approaching a flood giving sufficient depth for passage of boats. The conditions existing just at the mouth of the canal are very favorable for a continuation of that work, the bank being very abrupt and the approach to deep water very sudden.

At this point there is no indication of bar formation in the last 3 years, as shown by our profiles of canal cross sections.

West Pass retains approximately the same position it has occupied since it was formed by the natural action of the water draining from Centennial Lake.

No work of any kind was done in the harbor after the first part of November last, when I was put in charge of the levees in the Lower Mississippi levee district, until February 10, when we commenced to renew base lines and signals for locating dredges and have canal cross sectioned to obtain change since last survey on which to base present estimates.

Seventy-five thousand dollars was made available for the season's work, and on the 12th day of January, 1891, the contract was awarded to the Alabama Dredging and Jetty Company at 11.9 cents per cubic yard in scows for short haul and 13.9 cents for the long haul. Some slight modifications were made in the specifications for last year's work; the contractors to commence on or before ten days' notice expire, and complete it by December 31, 1891, and to excavate at least 4,000 cubic yards per day.

Owing to the fact that the woodwork of the dam across the lake was burned out in part during the autumn of 1890 there will be no long haul, it being possible for the tug and scow to pass through burned part of dike and dump along dam as heretofore in accordance with project.

The fire that destroyed a part of the dike occurred Sunday, November 2, 1890, at about 12 o'clock in the day. The structure was set on fire by young white men throwing a lighted match into the dry grass and rotten timber at base of dike. It burned from a point 800 feet east of De Soto Island to the Island.

I had the guilty parties arrested, and, the United States district attorney being absent, had them tried before a justice of the peace (and United States commissioner). The sympathy of the judge and some of the witnesses was with the accused, and the trial proved a farce, the prisoners being acquitted in spite of clear evidence of their guilt.

During February, 1891, the canal was cross sectioned for the purpose of finding the fill or change and the true sections on which to base the estimate for the present season's work.

The fills were found to be as shown in the following table, the volumes being obtained by the method of average end areas.

Estimate of material to be moved during 1891 in Vicksburg Harbor, canal and basin cut to +3 feet on the gauge.

Base of canal	100 feet.	Base of basin	300 feet.
Slope bar side	5 to 1	Slope bar side	5 to 1.
Slope land side	3 to 1.	Slope land side	3 to 1.

Station.	+Area.	—Area.	Net area.	Distance.	Cubic feet.	Cubic yards.
	Sq. ft.	*Sq. ft.*		*Feet.*		
28	0	0	0			
39	195	98	97	1,000	48,500	
40	280	111	169	100	13,300	
41	450	148	302	100	23,550	
42	257	68	189	100	24,550	
43	418	52	366	100	27,750	
44	520	47	473	100	41,950	
45	530	4	526	100	49,950	
46	575	22	553	100	53,950	
47	581	46	535	100	54,400	
48	563	36	527	100	53,100	
49	540	5	535	100	54,400	
50	532	37	496	100	51,500	
51	535	45	490	100	49,250	
52	450	155	295	100	39,250	
53	330	40	290	100	29,250	
54	228	140	88	100	18,900	
55	240	20	220	100	15,400	
56	315	115	200	200	21,000	
57	460	200	260	100	23,000	
58	640	45	595	100	42,750	
59	0	0	0	100	29,750	
Total					765,450	28,350
Total extra yardage in situ, due to deposit						28,350

Total extra yardage in scows due to deposit, 28,350+16 per cent. = 32,886.

The estimated yardage to be moved from last fall's soundings in situ = 481,399 cubic yards + 16 per cent. = 558,423 in scows. This with 32,886 added = 591,309 cubic yards measured in scows.

The next table shows the deposit in canal and basin since 1890, and amount to be dredged to the different horizontal planes, slopes, and base as heretofore. The partial volumes are added algebraically to the volume at the +3-foot plane to obtain the deposits to the different planes. Minus signs denote that the bed has been cut away and the plus denote deposit.

Range.	Distance.	+3-foot plane.		+2-foot plane.		+1-foot plane.		0 plane.		−5-foot plane.		−10-foot plane.	
		Net area.	Volume.	Net area.	Volume.	Net area.	Volume.	Net area.	Volume.	Net area.	Volume.	Net area.	Volume.
			Cubic feet.		Cubic feet.		Cubic feet.		Cubic feet.		Cubic feet.		Cubic feet.
29		0		0		0		0		0		0	
39	1,000	97	48,500	−20	−10,000	−45	−22,500	−50	−25,000	−95	−47,500	−135	−67,500
40	100	169	13,300	−5	−1,250	−10	−2,750	−20	−3,500	−55	−7,500	−125	−13,000
41	100	302	28,550	0	−250	0	−500	0	−1,000	0	−2,750	0	−6,250
42	100	189	24,550	−8	−400	−15	−750	−30	−1,500	−70	−3,500	−110	−5,500
43	100	366	27,750	−8	−800	−15	−1,500	−32	−3,100	−83	−7,650	−135	−12,250
44	100	473	41,950	0	−400	0	−750	0	−1,600	0	−4,150	0	−6,750
45	100	526	49,950	0	0	0	0	0	0	0	0	0	0
46	100	553	53,950	0	0	0	0	0	0	0	0	0	0
47	100	535	54,400	−10	−500	−20	−1,000	−25	−1,250	−60	−3,000	−80	−4,000
48	100	527	53,100	0	−500	0	−1,000	0	−1,250	0	−3,000	0	−4,000
49	100	535	54,400	+5	+250	+10	+500	+20	+1,000	+38	+1,900	+38	+1,900
50	100	495	51,500	+20	+1,250	+30	+2,000	+45	+3,250	+110	+7,400	+130	+8,400
51	100	490	49,250	0	+1,000	0	+1,500	0	+2,250	0	+5,500	0	+6,500
52	100	295	39,250	−3	−150	−6	−300	−5	−250	0	0	0	0
53	100	290	29,250	+10	+350	+20	+700	+35	+1,500	+75	+3,750	+75	+3,750
54	100	88	18,900	+25	+1,750	+40	+3,000	+70	+5,250	+150	+11,250	+190	+13,250
55	100	220	15,400	0	+1,250	0	+2,000	0	+3,500	0	+7,500	0	+9.500
56	100	200	21,000	0	0	0	0	0	0	−15	−750	−43	−2,150
57	100	260	23,000	+13	+650	+25	+1,250	+45	+2,250	+105	+4,500	+228	+2,250
58	100	595	42,750	+5	+900	+8	+1,650	+10	+2,750	+15	+6,000	+100	+16,400
59	100	0	29,750	0	+250	0	+400	0	+500	0	+750	0	+5.000
+10	10	0	0	0	0	0	0	0	0	0	0	0	0
Total			−765,450		−6,600		−18,050		−16,200		−31,250		−47,450
Cubic yards			28,350		−244		−669		−600		−1,157		−1,757
Total deposit			28,350		28,106		27,681		27,750		27,193		26,593
Amount soundings, 1890			481,399		560,781		642,615		729,286		1,199,023		1,715,412
Amount soundings, 1891			509,749		588,887		670,296		757,036		1,226,216		1,742,005

The totals to be dredged, in accordance with the soundings made in 1891, are as follows:

Horizontal plane.	In situ.	In scows.
	Cu. yards.	Cu. yards.
+ 3-foot plane	509,747	591,309
+ 2-foot plane	588,887	683,108
+ 1-foot plane	670,296	777,544
+ 0-foot plane	757,036	878,155
— 5-foot plane	1,226,216	1,422,410
—10-foot plane	1,742,005	2,020,725

The fill due to deposit during the year has been, estimating to the —10-foot plane, 26,593 yards.

The $75,000 allotted for the present season's work I have divided in my estimate as follows:

To cut the canal and basin to the 3-foot plane it will be necessary to move 591,309 cubic yards of material measured in scows, at 11.9 cents per cubic yard (it all being short haul), we have:

To cut to + 3-foot plane	$70,365.77
Inspection and office expenses, 10 months, at $450	4,500.00
Incidentals	134.23
Total	75,000.00

The dredge *Herndon* arrived here and commenced work March 4. Up to the 16th she only worked one crew, but the amount of excavation being so far below the required average, a double watch was placed on her. As heretofore, inspectors measure the yardage on each scow and sound the cut, keeping accurate records of all the operations and soundings.

The material dredged is being placed along the old dam, closing lake near Spengler's Mill, and dump watchmen are employed day and night to regulate position of each dump, to insure if possible an even surface to earthen dam.

The material moved to May 1 is as follows:

Dredge Herndon moved from canal.

	Cubic yards.
March, 1891	49,532
April, 1891	58,598
Total, in scows	108,130

All short haul, at 11.9 cents per yard. This has been paid for on monthly estimates, 10 per cent being retained.

A table of the currents in the canal from the beginning of this season's work to date, the velocities being obtained by running submerged floats, is submitted as follows:

Table of velocities of current and its direction, taken near mouth of canal (Range 45) during months of March, April, and May, 1891.

Date.	Gauge.	Change.	Velocity per second.	
Mar. 2	43.8	+0.3	1.173 running in	
3	44.0	+ .2	1.173 running in	
4	44.3	+ .3	Imperceptible	Water muddy.
5	44.6	+ .6	...do	
6	44.8	+ .2	...do	
7	45.3	+ .5	Slightly out	
8	Sunday		...do	Water clearing.
9	46.0	+ .7	...do	
10	46.1	+ .1	1.100 running out.	
11	46.4	+ .3	0.880 running out.	
12	46.6	+ .2	1.320 running out.	
13	46.9	+ .3	1.467 running out.	
14	47.1	+ .2	1.630 running out.	
15	Sunday			Water clear.
16	47.4	+ .3	No observation	

Table of velocities of current and its direction, etc.—Continued.

Date.	Gauge.	Change.	Velocity per second.	
Mar. 17	47.5	+ .1	1.467 running out.	Water clear.
18	47.6	+ .1	1.639 running out.	
19	47.7	+ .1	1.467 running out.	
20	47.7	.0	2.200 running out.	
21	47.8	+ .1	2.514 running out.	
22	Sunday.	....	....	
23	47.7	− .1	1.833 running out.	
24	47.7	.0	1.956 running out.	The variations in velocities are in great part due to difference in direction and force of wind.
25	47.75	+ .05	1.173 running out.	
26	47.8	+ .05	2.000 running out.	
27	47.8	.0	2.000 running out.	
28	47.8	.0	2.200 running out.	
29	Sunday.	....	....	
30	47.85	+ .05	No observation	
31	48.0	+ .15	2.493 running out.	
Apr. 1	48.0	.0	No observation	
2	48.1	+ .1	1.724 running out.	
3	48.1	.0	2.286 running out.	
4	48.1	.0	2.500 running out.	
5	48.0	− .1	Sunday	
6	48.0	.0	1.622 running out.	
7	48.0	.0	1.622 running out.	
8	48.0	.0	2.143 running out.	
9	47.95	− .05	1.666 running out.	
10	47.9	− .05	2.055 running out.	
11	47.9	.0	2.174 running out.	
12	47.9	.0	Sunday	
13	47.8	− .1	2.027 running out.	
14	47.75	− .05	1.685 running out.	
15	47.7	− .05	1.818 running out.	Water clear.
16	47.65	− .05	2.083 running out.	
17	47.6	− .05	2.324 running out.	Current in great part due to overflow water from Yazoo swamp.
18	47.5	− .1	2.255 running out.	
19	47.45	− .05	Sunday	
20	47.4	− .05	1.905 running out.	
21	47.4	.0	1.807 running out.	
22	47.4	.0	1.923 running out.	
23	47.45	+ .05	2.112 running out.	
24	47.45	.0	2.041 running out.	
25	47.4	− .5	2.112 running out.	
26	47.4	.0	Sunday	
27	47.45	+ .05	2.666 running out.	
28	47.45	.0	2.666 running out.	
29	47.0	− .05	2.143 running out.	
30	47.35	− .05	1.852 running out.	
May 1	47.3	....	Current out	
2	47.25	....	2.041 running out.	Water in canal clear.
3	47.15	....	....	
4	47.0	....	2.225 running out.	
5	46.83	....	2.091 running out.	
6	46.55	....	Current out.	
7	46.2	....	1.579 running out.	
8	45.8	....	1.177 running out.	
9	45.4	....	0.870 running out.	
10	44.8	....	Current out.	
11	44.2	....	0.100 running out.	
12	43.6	....	0.741 running out.	
13	42.8	....	Imperceptible	
14	42.0	....	0.300 running in	Slight current partly due to wind.
15	41.0	....	1.000 running in	
16	39.8	....	0.667 running in	
17	38.4	....	Slightly out	Water in canal clear.
18	37.0	....	...do	
19	35.5	....	...do	
20	33.5	....	0.417	
21	31.8	....	0.400	
22	30.6	....	Imperceptible	
23	29.0	....	...do	
24	27.3	....	...do	
25	25.6	....	...do	
26	24.1	....	Very slightly out.	
27	22.5	....	...do	
28	21.7	....	...do	
29	20.5	....	...do	
30	19.5	....	...do	
31	18.8	....	...do	

I will state here in connection with the harbor work that I am indebted to Mr. L. C. J. Baily, jr., assistant engineer, for valuable services rendered in making calculations, drafting, and other duties performed.

GREENVILLE, MISSISSIPPI.

The object of the work undertaken at Greenville has been to prevent the city front from caving into the river. In 1887-'88 ten submerged spur dikes were constructed in front of the town at a distance apart of 500 feet. In 1889 two spur dikes were constructed above these, as shown on accompanying map. These dikes temporarily stopped the caving along the city front, but the destruction continued in Bachelor Bend, above the town, the river eating into the bank until the part protected formed a salient projecting into the river. During the last freshet the river cut across this salient, destroying the two spurs constructed in 1889, and flanking the upper two of the series of 1887 and 1888.

The following extract from the report of Assistant Engineer Arthur Hider gives the condition of the work on June 1, 1891:

EXTRACT FROM REPORT OF ASSISTANT ENGINEER ARTHUR HIDER.

The caving in the bend above and in front of the upper part of the town of Greenville has been almost unprecedented during the late high water.

First, the upper dike was washed away and a few weeks afterwards the second dike was destroyed by the caving back of the bank in its rear. With these impediments removed the bend, which during the last 3 years had assumed an abnormal shape above, rapidly began to regain its natural form. This was not accomplished until the bank in front of where Dikes No. 1 and 2 stood had caved back from 800 to 900 feet, carrying with it the main levee and two protection levees, which were afterwards built in the rear, this caving extending downstream, cutting behind dikes 4½ and 5½.

At Dike 1 the caving was 820 feet; at Dike 2 the caving was 900 feet; at Dike 4½ the caving was 350 feet; at Dike 5½ the caving was 250 feet.

Above Dike No. 1 the caving gradually decreased in depth, but extended up into the bend a distance of about 3 miles.

The conditions here are such as to demand an early and active resumption of work. The funds now available are sufficient to complete about 6,500 linear feet of work similar to that done at Ashbrook Neck the past season.

This is probably all the work that can be done the present season.

To begin work at Dike 5½ and extend the improvement up in the bend as far as the funds will allow will take the revetment to Range 13 and still leave the upper part of the bend unprotected.

To place the work where, from the configuration of the shore line and the general direction of the current would indicate the point of most violent attack, the next high water would leave from 6,500 to 7,000 feet between the lower end of the proposed new work and Dike 5½ unprotected, with danger of serious caving along the unprotected bank. Under all the circumstances and the interests involved it will be advisable, perhaps, to begin at Dike 5½ and continue up to Range 13 rather than risk the danger of an attack both at, above, and below the proposed work.

Outside of the property interests involved in the recent disastrous caving it is thought that the shape of the bend above is in better shape for permanent improvement than heretofore.

The recent survey of this locality is shown on Plate 2.

Work will be resumed at this locality as soon as the river has fallen sufficiently to enable revetment to be constructed.

The project for this work, previously submitted and approved, will require to be materially modified to meet the changes caused by the last freshet.

LAKE BOLIVAR FRONT.

The object of this improvement was to stop the caving of the bank in front of the large levee across the end of Lake Bolivar, which was threatened by the rapid encroachment of the river.

Four thousand four hundred feet of revetment was constructed in 1888-'89, as described in the report of the Chief of Engineers for 1889, page 2,704, along a portion of which the mats were but 180 feet wide. This section was strengthened in 1889-'90.

The present condition of the work is shown in the following extract from the report of Assistant Engineer Arthur Hider, with whose recommendation that no work be done at this locality during the present season I concur.

EXTRACT FROM REPORT OF ASSISTANT ENGINEER ARTHUR HIDER.

The work done in protecting the bank in front of the important levee crossing Lake Boliver remains in good condition.

Below the end of the revetment work the caving has continued for the distance of 1¼ miles to Buck Ridge Landing, rendering necessary the construction of a new line of levees.

The hydrographic survey just completed shows that little or no change has taken place in the river channel except that the set of the current, which was formerly directly towards Lake Bolivar Landing, threatening the levee crossing Lake Bolivar, has now moved further down, rendering further apprehension for the future safety of this important levee needless.

A continuation of the revetment work further downstream would be desirable, but on account of more pressing necessity for immediate work at Ashbrook Neck, Greenville, and Louisiana Bend, which will tax the resources and capacity of the available plant to the utmost, no work is recommended at this particular locality the present season.

ASHBROOK NECK.

The object of this improvement is to prevent the river cutting through the neck, which at its narrowest point is only 2,300 feet wide, and thus forming a cut-off. An allotment of $300,000 was made for this work in 1890. The original project, approved by the Mississippi River Commission, recommended the construction of a series of spur dikes on the upper end of the neck similar to those constructed at Greenville.

After work was begun under this project, and two spurs partially constructed, the commission visited the work and modified the project to that of a continuous revetment.

After this change work was resumed, the bank for a distance of 6,000 feet was cleared of timber, 3,200 feet of the bank was graded, and 2,820 feet revetted at a cost of $30.42 per lineal foot.

To check the flow of water that passes over this neck and might precipitate a cut-off, two slashings were made parallel to the axis of the neck, one 7,000 feet long, the other 6,400 feet, and extending from some heavy timber to an old levee, which crosses the neck about 1,000 feet below its narrowest part. The saplings and small brush were cut 6 feet from the ground, and the stumps wattled so as to form hurdles, which have retarded the flow of water and caused a considerable deposit of sand.

While these hurdles have answered the purpose for which they were constructed, for the present season, I consider them of too flimsy a character and too liable to destruction and decay to be relied upon for any permanent protection during severe freshets.

It is recommended that they be replaced by a strong levee.

Work will be resumed at this locality as soon as the river has fallen sufficiently to enable revetment to be constructed.

The details of construction and the present condition of the work will be found fully explained in the accompanying report of Assistant Engineer Arthur Hider, who has been in local charge.

EXTRACT FROM REPORT OF ASSISTANT ENGINEER ARTHUR HIDER.

The following report of operations at Georgetown Bend is respectfully submitted.

The original project for this improvement adopted by the Mississippi River Commission to prevent the river cutting through Ashbrook Neck, which at its narrowest point is only 2,300 feet across, was the construction of a series of spur dikes on the upper side of the neck similar to those in front of Greenville.

"These spurs to be built of brush and stone, each dike resting on a foot mat 200 feet in length and extending out into the river from 300 to 350 feet, the spurs where the caving was most active to be located not more than 500 feet apart; on the remaining portions of the bank, the distance between spurs to be increased at the discretion of the officer in charge."

A survey of the locality was made and a plan prepared, and submitted on October 6, 1890, for the construction of seventeen spurs, protecting about 8,500 linear feet of the bend where the caving was most rapid and shielding the narrowest part of the neck.

It was expected to finish ten of these before the annual rise set in, and the remainder the next low-water season.

To carry out this project a party was organized October 27, 1890, to load stone on barges for this work from the reserve at Arkansas City. Another party was organized on November 1, part of the plant towed from Greenville, and work begun clear-

ing the bank of brush and trees, getting the boats in position preparatory to beginning mat building. On November 7, the hydraulic grader began work, and on the 8th, the building of foundation mat for dike No. 8 was commenced; brush was received from the contractors on the 10th.

The foundation mat for Dike No. 8 was sunk in place, the construction of the crib begun, and the foundation mat for Dike No. 10 completed when the Commission visited the work on November 24, and modified the plan from that of detached spurs to that of continuous revetment; "the submerged mattresses to have a width below low water of from 250 to 300 feet, according to locality; the bank above low water to be graded before placing of the submerged mattresses, and to be covered with a layer of riprap about 10 inches thick to a height of about the two-thirds full stage; two or more slashings not less than 30 feet wide, each to be made along the axis of the neck, the saplings to be cut off at a height of about 6 feet from the ground and the tops carefully wattled among the stumps. For this season's work the point at which the upstream spur was begun to be retained as the origin of the work; the work to be extended downstream a distance of 6,000 feet at the earliest practicable moment, and subsequently extended both upstream and downstream as necessity may require."

In accordance with this modified project the revetment was made continuous by building mats 350 feet wide between the foundation mats for the dikes already constructed.

Clearing.—The bank for a distance of 6,000 feet from the upper end where work was begun was cleared of all brush, trees, and logs for a distance back of 230 feet; such of the brush and poles as were suitable were utilized in the work as it progressed. The large timber where liable to cave in the river, form snags, and obstruct next season's work was cut down; in all, about 31$\frac{6}{10}$ acres was cleared.

Grading.—The bank at the upper end of the work is nearly all sand, and continued caving while the mattress work was in progress.

Advantage was taken of the low stage in the early part of December to regrade the lower part of the slope which had been previously graded at a higher stage of water.

At some points the sand caved so rapidly while the hydraulic grader was at work that hand grading had to be resorted to to bring the upper bank to the proper slope, which varies from 1 on 3 to 1 on 5. A single jet was used, hose 4 inches diameter, nozzle 1$\frac{3}{4}$ inches and 1$\frac{1}{2}$ inches, pump pressure 160 pounds, steam pressure 80 pounds.

The light character of the soil, and the rapid current setting straight into the bank, caused a great deal of caving, and rendered necessary a large amount of regrading, besides the building of two large shore mats to connect the mattress work with that of the upper bank.

Grading began November 7, and was finished for the season January 5, 1891; the grader was in service 50 days and graded 3,200 linear feet of bank, from 25 to 30 feet in height, an average of 64 linear feet for each working day.

Spur-dike and mattress construction.—But one spur dike was put in, owing to the modification in the plan; this consisted of a single crib of standard construction, except that the frame was made of gum-lumber posts 3 by 4 by 7 inches. Bottom and top frames 2 by 6 inches by 16 feet fastened at the joints with $\frac{1}{2}$-inch carriage bolts. This crib was 210 by 32 by 7 feet, and located at the beginning of the work, and rested on a foundation mat 200 feet in length by 345 feet wide, the foundation was built and sunk in place before the change was made to continuous revetment. Both of these foundation mats were utilized as parts of the continuous revetment, by filling up the space between them, with other mats 300 feet wide.

The work of building the wide 300-foot mats was continued until January 2, 1891, when it was deemed advisable to stop mattress construction and finish up complete the upper bank revetment, as the river was rising rapidly above and a threatened rise of some 20 feet was expected.

The river actually rose from December 28 to January 17, 19$\frac{1}{10}$ feet. By the time the upper revetment work was finished, it became evident that it would be unsafe and extremely hazardous to undertake the further continuance of the construction of the 300-foot mats in the rapid current that developed and subject to the dangers from drift.

In accordance with your instructions and in order to utilize the brush and poles on hand, as the upper bank had already been graded, a mattress the width of one mattress boat (180 feet) was built 500 feet long and sunk in place.

The remainder of the brush and poles not used, was unloaded from the barges, and what stone remained was unloaded on the bank about 1 mile above Offutt Landing, for use the next season.

To check the flow of water that passes over this narrow neck at flood stages and to prevent the formation of channels which might precipitate a cut-off, two slashings approximately parallel with the axis of the neck, were made, beginning at an

old levee that crosses the neck about 1,000 feet below the narrowest part, and extending into the large timber above.

The one nearest the upper side is about 900 feet from the river at the narrowest point, and 7,000 feet in length; the other is 500 feet from the river on the lower side and 6,400 feet in length; the distance between the two lines of hurdles is about 900 feet.

The saplings and small brush were cut off about 6 feet from the ground, and the tops used in wattling between the stumps.

Where there were no trees, posts were set in the ground, all ditches and gullies crossing the neck were obstructed by building earthen dams across them at intervals.

Below is a statement showing the amount of completed work:

	Feet.	Squares.
Main mattress built:		
No. 1	200 by 345	690.00
2	200 by 345	690.00
3	728 by 300	2,184.00
4	515 by 300	1,545.00
5	373 by 300	1,119.00
6	520 by 300	1,560.00
7	500 by 180	900.00
Total lineal feet	3,036	8,688.00
Shore mat built:		
No. 1	220 by 35	77.00
2	280 by 108	302.40
3	480 by 50	240.00
Total lineal feet	980	619.40
Upper bank revetment:	2820 by 65.3	1,842.60
Total squares of revetment	....	11,150.00

The actual length of bank covered with revetment and subaqueous mattress was 2,820 linear feet, 216 linear feet being taken up by overlapping of mattresses.

The amount of brush used per square of completed revetment work was: Brush 0.708 cord; poles, 0.136 cord, total brush and poles per square, 0.84 cord.

The amount of stone used per square of completed work was 1.08 cubic yards.

Crib work.

210 by 32 by 7 feet.
30 by 16 by 3.6 feet ....cubic feet.. 51,560

The amount of material used was 200 cords of poles and 180 cubic yards of stone.

Grading.

3,200 linear feet of bank from 25 to 30 feet high.

Clearing.

6,000 by 230 feet ....acres.. 31.6

Hurdling.

13,400 by 6 ....squares.. 804

he amount and value of material expended is as follows:

B ush (7,901.1 cords)	$8,128.63
P es (1,722.8 cords)	3,296.15
S ne (12,184.8 cubic yards)	27,507.48
W e cable, three-eighths-inch diameter (8,700 pounds)	939.60
W e cable, three-eighths-inch diameter (50,284 pounds)	1,996.60
W e, galvanized, (92,016 pounds)	3,184.28
S es (16,740 pounds)	645.08

Coal		$3,266.85
Oil		259.14
Medicines		114.57
Lumber		494.80
Clevises		67.50
Bolts		46.55
Supplies		114.09
Permanent supplies (one-half cost charged)		513.87
Rope (one-half cost charged)		950.07
		51,534.26
Labor (pay rolls)	$28,425.27	
Subsistence stores	6,765.84	
		35,191.11
Traveling expenses and transportation		282.21
Office expenses (Memphis)		195.78
Total		87,203.36
Deducting the cost of 13,400 linear feet hurdling 6 feet high, built on the neck, parallel with the axis, 804 squares, at $1.19	955.40	
1,821 cubic yards stone, unloaded on bank for next season's work, at 25 cents	455.25	
		1,410.65
Leaving the cost of the revetment work		85,792.71

Cost per square of completed work, $\frac{\$85,792.71}{11,150}=\$7.69$.

Cost per linear foot of completed work, $\frac{\$85,792.71}{2,820}=\$30.42$.

The percentage of the cost of the different items is:

	Value.	Per cent.
Materials and supplies	$48,267.41	55.36
Towage	6,115.04	7.01
Labor	22,680.51	26.01
Subsistence	8,224.64	9.43
Office and traveling expenses	361.50	0.41
Superintendence	1,554.17	....
Total	87,203.36	100.00

The extreme width (300 feet) was adopted for the subaqueous mattress, as at the point where the work was done the current at midstage set directly into the bank.

It is thought that the place of greatest danger, and where the caving was the most active, is protected by the work done last season, but it is absolutely necessary to supplement this by continuing the improvement both above and below during the next low-water season, to render the improvement permanent.

* * * * * * *

The work put in last season has stood the past flood remarkably well. The improvement was begun very late in the season, November 1, and was stopped by the high stage of the river January 17, 1891, when only 2,820 feet of revetment had been completed. Five hundred feet of this at the lower end, on account of the swift current, drift, and other difficulties peculiar to this class of work at high stages, was necessarily constructed with a narrow mattress 180 feet wide, which only partially protected the foot of the bank.

This part of the work has settled, due to scour under the outer edge of the mat, which under the circumstances of the case was of inadequate width, but the best that could be done.

The rest of the revetment is intact and in good condition.

The entire work was subjected to an enormous and unusual strain, due to its location. It was located so as to shield the narrowest part of the neck, where the

caving had been the most active and the over pour across the narrow part the greatest.

Under these circumstances the results attained are extremely gratifying.

Work should be continued on this improvement, both at the upper and lower end, as soon as practicable, so as to finish the contemplated extension the present season.

Even this accomplished, it may be necessary to revet the under side of the peninsula, as the recession the of bank in Rowdy Bend below Gaines Landing indicates that an attack will next be made here, caused by the current being deflected across from the Arkansas side to the lower side of the neck.

The two lines of brush hurdles placed parallel with the axis of the neck offered considerable resistance to the flow of water at high stages across the neck, and where protected by undergrowth remained standing and caused a very considerable deposit at places. In this connection it may be said that a levee running down the middle of the neck, built above the high-water line, as originally recommended, would probably give better results.

The current induced by the difference of slope between the river on the upper and lower side of the neck, which is only 2,150 feet across, while the distance around is 8 miles, is sufficient to lead to serious apprehension that a channel may form and a cut-off be precipitated thereby during high water unless this flow is checked.

The hurdles built are to a certain extent efficacious, but it is doubted if they present a sufficient obstacle to prevent all danger from this cause.

Plate 1 shows the present condition of this improvement.

LEVEES.

Plates 4 and 5 are profiles showing the heights of levees in the Third District in 1880 and 1891, and the flood heights of 1882, 1890, and 1891.

Tables accompanying this report give the yardage and cost of the levees constructed by the United States in the district to January 1, 1891.

Under the river and harbor act approved September 19, 1890, the Mississippi River Commission made the following allotments for levees in Third District, of which 5 per cent. was to be retained for high-water protection:

Levees, Lower Mississippi Levee District	$198,000
Levees, Tensas Basin, Third District in Arkansas	190,000
Levees, Tensas Basin, Third District in Louisiana	95,000

Under these allotments proposals were invited for building levees November 8, 1890, and opened November 18, 1890.

The following is an abstract of the bids received:

Abstract of proposals for enlargement of levees, Lower Mississippi Levee District.

[Received and opened by Capt. S. W. Roessler, Corps of Engineers, November 18, 1890.]

No.	Name of bidder.	Timber-lake to Port Anderson.	Port Anderson to Offutt.	Offutt Front.	Skipwith.	Longwood.	Clover Hill.
2	A. Arnold	26½	27½				
4	Ernest Hyner	24½	25	29			
5	P. F. Lamb	30	26				
6	Harvey & Scott	*22	22	*28			
8	W. L. Killebrew			34½	38	34½	
14	Robert Johnson	33	28	32½			
17	A. R. Fudge		*22				
19	Carey Bros	27	28	30			
22	Timothy Sullivan					*30	*21

* Contract made.

Abstract of proposals for construction and repair of levees, Tensas Basin, in Arkansas.

[Received and opened by Capt. S. W. Roessler, Corps of Engineers, November 18, 1890.]

No.	Name.	Brooksfield.	Boggy Bayou	Lucca Loop. Long time.	Lucca Loop. Short time.	Luna.	Columbia.	Leland.	Sunnyside.
		Per yd.	*Per yd.*	*Per yd.*	*Per yd.*	*Per yd.*	*Per yd.*	*Per yd.*	*Per yd.*
1	Flynn & De Garis			$0.22½	$0.41				$0.16¾
2	A. Arnold		$0.29	.22	.27	$0.22	$0.21	$0.22	.17
3	Levi W. Webb							.22	
4	Ernest Hyner								.17
5	P. F. Lamb			.23			.23	.17¾	.17½
6	Harvey & Scott	$0.28	.29	.20½		.20	.20	.20	.18
7	Hogan & Buchanan								.17½
8	W. L. Killebrew			.20½					.19
9	J. S. Gant					.24½	.23	.23	.18½
11	J. M. Whitehill	*.25	.28	*.18½	.28				
12	E. O. & W. S. Withers			.19	.25	.21	.19	.18½	.18½
13	T. S. Aderholdt & Co					.26	.24½	.22½	
14	Robert Johnson	.28½	.28½	.23½	.35				
15	Andrews & Ogden			.23$\frac{15}{100}$	.33			.19$\frac{25}{100}$	.19¾
17	A. R. Fudge		*.24¾						
18	The Sunnyside Co					.19¾			*.16
19	Carey Bros		.27	.19					
21	Robert E. Craig		.28	.21		*.19	*.18	*.17½	.16

*Contract made.

Abstract of proposals for construction of levees, Tensas Basin Front, in Louisiana (Elton).

[Opened by Capt. S. W. Roessler, Corps of Engineers, November 18, 1890.]

No.	Name of bidder.	Per yard.
2	A. Arnold	$0.26½
6	Harvey & Scott	.24
10	Peter Trezevant	.27½
15	Andrews & Ogden	.27¾
16	Edmund P. White	.24
20	John Scott & Son	*.23½

* Contract made.

LEVEES, LOWER MISSISSIPPI LEVEE DISTRICT.

The levee section generally adopted within the last few years by the local authorities had a crown of from 4 to 6 feet, slopes from 1 on 2½ to 1 on 3, and a narrow berme on the river side. This section has recently been increased to a width of crown of 8 feet, slopes 1 on 3, and a berme of 30 feet. The levees constructed during the last fiscal year by the United States have conformed to these dimensions.

The following is an estimate of the yardage required to complete the levees in this district as estimated by the Lower Mississippi Levee Board June 1, 1891:

	Cubic yards.
Amount required to raise levees to a grade equal to calculated high water of 1890	2,076,300
To 1 foot above	3,912,500
To 2 feet above	6,281,600
To 3 feet above	8,799,000

From these estimates are to be deducted the yardage put up since January 1, 1891, by the United States, and that still under contract, which is about 616,000 cubic yards.

The work done by the Lower Mississippi Levee Board from June 1, 1890, to June 1, 1891, was 1,492,973 cubic yards.

In the following table is given a list of the levees constructed and enlarged by the United States, and their cubic yards completed during the fiscal year ending June 1, 1891:

Levee enlargement work, Lower Mississippi levee district, under contract with the United States.

Name of levee.	Location on inch to mile map.	Length.	Complete to June 1, 1891.	Amount yet to do.	Total quantity.	Contractors.
		Feet.	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	
Timberlake	441–443 L	10,025	34,880	14,620	49,500	Harvey & Scott.
Port Anderson	443–444 L	10,000	30,800	4,200	35,000	A. R. Fudge.
Offuts Front	444–478 L	72,265	321,179	33,112	354,291	Harvey & Scott.
Longwood	502 L	14,500	61,825	....	61,825	Timothy Sullivan.
Clover Hill	534 L	6,570	22,057	11,712	33,769	Do.
Upper Skipwith	528 L	6,580	7,395	36,548	43,943	Carey & Mims.
Lower Skipwith	529 L	5,641	7,800	15,788	23,588	L. C. Dulaney.
Total	....	125,561	485,936	115,980	601,916	

In addition to the above, the United States has built two loops above Greenville of about 16,000 cubic yards.

The contractors were generally slow in beginning operations and failed to have a sufficient force to complete their work within the time specified, *i. e.*, March 1, 1891.

In January and February an extra force was employed by the General Government on the Port Anderson and Offuts Front Levees, and the cost thereof was charged to the contractors.

The contracts were extended to July 1, 1891, at which date it is expected all the levees under contract will be completed except the Timberlake and Clover Hill levee, along some portions of which the borrow pits are now filled with water, and it has been impracticable to resume work.

These levees were under local charge of Assistant Engineer Coppee until February 15, and since that date under Assistant Engineer Hider.

LEVEES, TENSAS BASIN, ARKANSAS.

The old levees in this front have generally a 4-foot crown with slopes 1 on 3, and are from 1 to 3 feet lower than the corresponding levees on the Mississippi side.

They cross few sloughs, are generally well protected by timber on the river side, and except near Lucca and Sunnyside, where it is expected to build new levees this next season, they are distant from caving banks.

The following summary of an estimate prepared by Assistant Engineer E. C. Tollinger of the yardage required to raise the levees to the stated height above the assumed high water of 1890, with a crown of 8 feet, and slopes of 1 on 3, is submitted.

The high-water line of 1890 assumed is that which it is estimated the freshet would have attained if there had been no breaks in the levees, and is 17 feet above that which existed at Arkansas City, and 23 feet above that at Greenville, Miss.

Summary.

Total for 1 foot above high water, 1890.	Present levee.	Additional yardage required.			Remarks.
		For 1 foot above high water, 1890.	For 2 feet above high water, 1890.	For 3 feet above high water, 1890.	
Cubic yds.	*Cubic yds.*	*Cubic yds.*	*Cubic yds.*	*Cubic yds.*	
1,951,243	967,474	983,769	1,206,013	1,480,360	Amos Bayou to Arkansas City.
2,102,790	1,222,167	880,623	1,172,223	1,483,681	Arkansas City to Linwood.
4,054,043	2,189,641	1,864,392	2,378,236	2,964,041	Amos Bayou to Linwood.
681,106	760,467	920,459	1,230,500	1,572,623	Linwood to Lakeport.
995,121	657,621	1,337,500	1,732,073	2,134,359	Lakeport to Louisiana line.
730,270	3,607,909	4,122,351	5,340,809	6,670,023	Amos Bayou to Louisiana line.
386,514	180,395	206,118	267,040	333,501	5 per cent. for contingencies.
116,784	3,788,304	4,328,469	5,607,849	7,003,524	

NOTE.—This table does not include work under contract by United States, by State forces, nor the extension of the line to connect with the levees on Arkansas River.

In the following table is shown the levee work undertaken by the General Government, the Tensas Basin Levee Board of Louisiana, and Desha County Levee Board

of Arkansas, from Amos Bayou to the Louisiana State Line, from May 1, 1890, to May 1, 1891. Construction grade elevation above high water of 1890 is 3 feet with an 8-foot crown, slope 3 to 1.

Location.	Length of work. New levee.	Length of work. Old levee.	Earthwork.	Price per cubic yard.	Cost of each contract.	Remarks.	Contractor.
	Feet.	*Feet.*	*Cu. yds.*	*Cents.*			
Brookstield, Desha Co.	902	....	16,575.2	25	$4,143.80	United States Government.	J. M. Whitehill.
Boggy Bayou, Desha Co.	1,785	....	90,703.4	24¾	22,449.09	....do	A. R. Fudge.
Lucca Loop extension, Desha Co.	16,524	....	462,859.5	....	84,446.86	....do	J. M. Whitehill.
Sappington, Desha Co.	963	....	10,620.6	19 11/16	2,090.93	Tensas Basin .	Do.
Ferguson, Desha Co ..	471	....	6,840.2	19 11/16	1,346.66	....do	Do.
Chicot, Desha Co	650	....	8,706.8	19 11/16	1,714.15	Desha Levee Board.	Do.
Arkansas City, Desha Co.	1,291	....	27,487.2	19 11/16	5,411.55	Tensas Basin .	Do.
Luna, Chicot Co	1,630	....	32,205.4	19	6,119.03	United States Government.	R. E. Craig.
Columbia, Chicot Co ..	1,480	....	17,453.2	18¾	3,272.30	....do	Do.
Leland Short Line, Chicot Co.	4,670	....	44,805.7	17¼	7,491.00	....do	Do.
Sunnyside Front, Chicot Co.	16,330	....	43,100.0	16	6,736.00	....do	Sunnyside Land Co.
North of Arkansas City, Desha Co.	....	2,829	26,680.0	19 11/16	5,252.62	Tensas Basin .	J. M. Whitehill.
Do	....	10,070	10,200.0	19 11/16	2,008.13	....do	Do.

As in Mississippi, work has been delayed by the contractors being slow in commencing operations, and by excessive rains, none of the levees under contract by the General Government were completed within the time called for by the specifications. The contracts have been extended to July 1, 1891, at which date it is expected that the levees will be practically completed, with the exception of the Lucca Loop extension, on which levee the contractor has until February 1, 1892, to complete his contract.

The levees of the Tensas Basin leave the Mississippi River at Cypress Creek and extend along that creek to Boggy Bayou. Between Cypress Creek and the Arkansas River is a tract of country unprotected from overflow, while around the head of the levees during freshets a flood of water flows into the bayous and swamps of Lower Arkansas and Louisiana.

To fully protect the Tensas Basin it will be necessary to extend the existing line of levees to connect with the levees on the Arkansas River, and to repair the Arkansas River levees for some distance up that river. A survey of two lines for that purpose was undertaken in 1889. Captain Rossell's report upon that survey is appended. His estimate of 1,621,198 cubic yards is based upon flood heights previous to 1890. To raise the levees to 1 foot above the assumed flood heights of 1890 would increase that estimate to 2,231,362 cubic yards.

LEVEES, TENSAS BASIN, LOUISIANA.

The profile of these levees is much stronger than those of Arkansas. They are in general not of sufficient height, and are situated close to the river, so that they are more liable to be destroyed by caving banks.

The estimated yardage necessary to raise the levees of this basin in the third district to a height of 3 feet above the high water of 1890, with 8-foot crown and slope of 1 on 3 on river side, is 2,795,844 cubic yards as estimated by the chief State engineer, H. B. Richardson, of Louisiana, whose letter is appended.

The general Government has under contract the new Elton levee (538 to 541), which was built in rear of an old levee which was threatening to cave into the river and has since in large part been destroyed; 315,000 cubic yards were completed June 1. Considerable trouble was experienced in crossing a willow slough, where the levee for a distance of 400 feet, when nearly completed, began sinking and forcing out a weak underlying stratum. This sinking continued until a test gauge at station 148 + 50 indicated a lowering of the surface of 24 feet. The ground in rear of the levee was upheaved a maximum distance of 12½ feet, and forms a berme for a dis-

tance of 100 feet with a width of 35 feet on top and about 50 feet at the bottom. The contractor has a large force at work on this levee, and it is expected that it will be completed early in July.

HIGH WATER PROTECTION OF LEVEES.

As soon as this year's freshet had attained such a height as to cause apprehension in regard to the safety of the levees, forces were organized for high-water protection. The towboat *Osceola* was employed on inspection service and in transporting material for the levees in Mississippi and Arkansas, and the steamer *Meigs* patrolled the Louisiana front. The towboat *Vidalia*, which was employed in gauging the river at Arkansas City, was held in readiness to assist the *Osceola*, but fortunately her services were not required. The assistant engineers who had been employed on levee construction were assigned to local charge of levee protection, and inspectors were distributed at critical points. Measures were taken to repair all dangerous points, and sacks and lumber were distributed so as to be available at threatened localities. The State forces had also early organized and had adopted a system of patrolling the levees, which was of great value in giving warning of threatened danger. The General Government only attempted to guard and patrol levees in exceptional cases, such as where the line was in an uninhabited region, or where there appeared to be danger of attempts being made to cut the levee.

The following allotment for high water protection was made by the Mississippi River Commission and approved by the Secretary of War, March 20, 1891, which enabled work to be prosecuted with increased vigor:

Levees, Lower Mississippi levee district	$82, 750
Levees, Tensas Basin, third district, Arkansas	47, 500
Levees, Tensas Basin, third district, Louisiana	34, 062

The principal sources of trouble were the sloughing off of the back slope, particularly where new work had been put on the land side, wave-wash on levees which were not properly sodded, too low levees which required to be topped to prevent the water flowing over them, and a seepage through the levees near and under the base frequently attributed to crawfish holes.

Three crevasses occurred in the third district during the freshet. The first on March 21, near Concordia, La., (549 R); the second near the Stella plantation, Mississippi, (503 L), on the night of April 3, and the third in front of Greenville, April 22. The first 2 crevasses occurred in old levees which were considered perfectly safe, and therefore had not been carefully inspected. The one in front of Greenville was due to the caving in of the river bank, had been anticipated, and a back levee had been partially constructed. This levee was raised above the water level a few hours after the break occurred, and the crevasse closed.

The Concordia break gradually assumed a width of 1,600 feet, and had a maximum flow through it of 100,000 cubic feet per second. Efforts were made to hold the ends by covering them first by mats of sand bags and bagging, then by a mat of brush and sand bags, and finally, by building out spur dikes of brush, piles, and sand bags approximately at right angles to the levee, which deflected the water from the end to be protected. This last method was successful.

The ends of the Stella Crevasse were successfully held by similar dikes, the crevasse widening to 422 feet. The maximum discharge through it was found to be 19,000 feet per second. In front of the crevasse was a private levee, which had been overtopped during the freshet, and a number of gaps washed through it. The Board of Mississippi Levee Commissioners undertook the closing and raising of this private levee. Between April 14 and May 7 they closed 10 breaks, aggregating a length of 2,500 feet, and having a depth of from 2 to 8 feet, and materially reduced the flow of water through the break, which on May 5 was found to be 2,800 cubic feet per second. Work was then abandoned, as the river was falling so rapidly that further expenditure was not deemed advisable.

To Assistant Engineers Arthur Hider, E. C. Tollinger, and Henry Goodrich, great c dit is due for the zeal and intelligence they displayed throughout this struggle w h the high water, and to whose untiring efforts the success achieved in holding t levees is largely due.

FRESHET OF 1891.

he water reached its highest point in the Third District about the 4th of April. t the upper and lower end of the district it was very considerably below that of l year, while in the vicinity of Lake Providence, and for some distance below, it

was equal or slightly above that of 1890. Below is the height attained at a few points.

Locality.	Distance below Cairo.	
	Miles.	
Mouth of White River	393.0	2.7 feet below 1890.
Mouth of Arkansas River	401.8	2.4 feet below 1890.
Arkansas City	438.3	1.15 feet below 1890.
Greenville	479.0	0.20 feet below 1890.
Wilson Point	531.5	0.20 feet below 1890.
Lake Providence	542.5	0.10 feet above 1890.
Henderson	573.5	0.05 feet below 1890.
Vicksburg	599.0	1.00 feet below 1890.
Warrenton	607.0	1.00 feet below 1890.

The area overflowed on the right bank, due to the Concordia Crevasse, was only 13.5 per cent. of the land submerged in 1890, and was confined to East Carroll and Madison parishes. In East Carroll Parish 148 square miles were overflowed; in Madison Parish 270 square miles were overflowed; total, 418 square miles. Area overflowed in 1890, 3,050 square miles.

On the left bank only 29.3 per cent. of the land submerged last year was overflowed. This was due to the Stella Crevasse (503 L), and the Robertsonville Crevasse (338 L) in the Second District. The area submerged in Bolivar County was due to the crevasse at Robertsonville.

In Bolivar County 62 square miles were overflowed; Washington County, 63; Issaquena County, 177; Sharkey County, 100; Warren County, 152; total, 554 square miles. Area overflowed in 1890, 1,889 square miles.

A map showing the limits of the overflow due to these crevasses, from a reconnoissance made after the water subsided, is submitted. (Plate 6.)

Attention is especially invited to the following modifications in the construction of levees proposed by Assistant Engineer Arthur Hider.

The necessity for greater care in selecting material for the foundations of levees has been forcibly shown during this freshet. For high levees Mr. Hider's curves give a rather large banquette.

PROPOSED SECTIONS FOR LEVEES.

The lessons taught by the last high water are but a repetition of the experience gained by the previous overflow, and only more thoroughly demonstrated the urgent necessity that the greatest care be exercised in levee construction.

During the period when the water is at or near their tops, the most careful inspection and guarding is required to prevent disaster. In the report of last year the following recommendations were made to avoid a recurrence of the disastrous crevasses that then took place.

(1) A greater height of embankment.

(2) A larger section.

(3) More care in selection of material and in details of construction of the foundation.

(4) The addition of a berm on the land side, where the material is porous, to give the necessary weight and stability to counteract the water pressure from the river side.

The experience of the present season, both in enlarging and strengthening old levees and in protecting them from damage during the flood, only tends to render more apparent the necessity that the greatest care be exercised in their construction, and fully bears out the general recommendations then made, which are here reiterated and elaborated more in detail.

In former years it has been the practice to build these embankments at the lea possible cost, and to this end to use the material closest at hand, with little, if an selection,—in other words, to build a bank of earth of the nearest available materi to keep out the water during the time of flood.

While the greater part of the front was unleveed and the embankments were small dimensions and of no great height, the weak features in this method of co struction were not so apparent, but as the levee system was extended from year year, rendering necessary the building of much higher and larger embankments restrain the annual floods, the frequent crevasses, from unknown causes and witho apparent weakness at the particular locality, demonstrated that the fault lay eitl

in the method employed in their construction, or that defects existed in the foundation itself upon which they rested. It can hardly be expected that levees constructed as at present, with light porous soil, and the vegetable matter near the surface of the natural ground distributed through the main body of the embankment, to withstand the pressure of water for 3 or 4 months each year, without a thorough saturation and consequent leakage, enough to menace the stability of the embankment, unless they are made of unnecessarily large dimensions.

The sections generally adopted in Mississippi until within the past few years were, crown 4 to 6 feet, slopes from 3 to 2½ on 1, and a narrow berme on the river side of from 8 to 12 feet. Fig. 1, Plate (7). The dimensions are being increased to a standard of 8 feet crown, slope 3 to 1 on each side, and a berme of at least 30 feet on the river side. Fig. 2.

The plan of levee building formerly pursued was:

(1) To chop down the brush and trees within the space to be occupied by the base of the levee, and cut off the stumps even with the ground, leaving the rest of the stump and roots to rot in the levee.

(2) Then to plow up the surface to be covered by embankment.

(3) To dig "muck" ditch from 4 to 6 feet wide and 6 feet deep, which was filled with earth and loosely compacted.

(4) The earth to form the embankment was then indiscriminately deposited without selection, the borrow pits being from 6 to 8 feet deep, and often within 10 feet of the base of the levee, the earth being obtained from the river side.

By proceeding in this manner the vegetable material and top soil is loosened under the base of the levee, and as the borrow pits are uncovered the first material obtained, which is the top soil, naturally finds its way into the base of the levee. Supposing this top soil (full of grass roots and other decaying vegetable matter) to be 1 foot thick, we have the base of the levee composed of from 1½ to 2 feet of porous soil, depending upon its distribution. This is the part of the levee subjected to the greatest pressure, and, from the character of the material of which it is composed, is least adapted to withstand the strain and prevent the percolation of water under pressure; the consequence is that nearly all of the old levees have serious leaks at and just above the surface of the ground.

During high water it will be found that along the inside of the levee the ground is thoroughly saturated with sipe water, and as the roadway for travel is located here, each vehicle or animal passing only tends to make the ground more soft and boggy, so that in a short time the road is absolutely impassable for vehicles, and frequently for horsemen. To mitigate this evil, a drainage ditch is often cut to drain this water at a short distance from the base, which increases the danger of the water forcing itself through from the river side.

The changes in the present method of construction suggested are:

(1) To clear the base of the levee, grubbing out all stumps and roots.

(2) To plow up the surface of the ground to be occupied by the levee and also that under the berme or banquette which is to be built on the land side.

(3) To use all the top soil containing roots or other perishable material from the base of the levee, as well as from the borrow pits, to form the banquette and roadway on the land side.

(4) To construct a muck ditch of selected material of suitable dimensions in the center of the levee.

The earth to be thoroughly compacted.

(5) To construct the levee proper with material obtained from the borrow pits, after all soil and decaying vegetable matter has been removed.

(6) No borrow pits to be within 40 feet of the base of the levee and to be not more than 5 feet deep.

The advantages of the method proposed are that the material where the pressure is greatest, viz, at the foot of the slope, is the best available and free from decaying vegetable matter.

The banquette affords additional section where most needed, and prevents dangerous leakage and sipage, as the additional distance the water has to percolate destroys to a great exsent its power to transport material through the embankment. It affords a roadway at all seasons of the year without injury to the main levee, an important consideration during high water. The danger from insecure foundation or from levees built on porous soil is very much reduced, as the additional weight of the banquette on the inside of the levee prevents the water forcing its way up near the foot of the inside slope. It is proposed to restrict the height of levees without a banquette on the inside to 6 feet, the banquette to be of a constant width on top of 40 feet and 6 feet below the top of levee, with the outer slope of 2 on 1, and to be used as a roadway. A section of the proposed levee is shown by Fig. 3. The additional cost of the section proposed, compared with that now adopted as to standard, is given below for every 2 feet in height from 6 to 20 feet.

Additional cost of proposed section over that now used as standard:

Height 6 feet, 12 per cent.
Height 8 feet, 37 per cent.
Height 10 feet, 44 per cent.
Height 12 feet, 45 per cent.
Height 14 feet, 43 per cent.
Height 16 feet, 40 per cent.
Height 18 feet, 36 per cent.
Height 20 feet, 34 per cent.

By reducing the width of the banquette to 20 feet, a section which is shown (Fig. 4):

The increase of cost over the standard section is:

Height 6 feet, 12 per cent.
Height 8 feet, 21 per cent.
Height 10 feet, 23 per cent.
Height 12 feet, 22 per cent.
Height 14 feet, 20 per cent.
Height 16 feet, 17 per cent.
Height 18 feet, 15 per cent.
Height 20 feet, 13 per cent.

The section of levee recommended is that shown by Fig. 3 and 5 with banquette 40 feet wide.

A comparison showing the increase of yardage for different heights in levees in 100-foot sections with a 20-foot and 40-foot banquette on the plan proposed, compared with the standard section, is shown in Fig. 6.

The additional cost, it is believed, is more than offset by the benefits derived.

Security to those who are dependent upon levees for protection and immunity from overflow is, of course, the paramount consideration. Any plan that will insure this will justify a very considerable outlay to obtain those desirable results. The modifications are suggested with this end in view.

With levees of sufficient height, carefully constructed upon the plan outlined above, the dangers of crevasses will be greatly reduced, and the line of levees made reasonably safe.

REPAIRS AND CARE OF PLANT.

The floating plant and other property, when not in use, have been cared for about 1 mile below Greenville. There has been no loss of boats or barges during the year. The steamer *Etheridge* has been transferred to the general service, to facilitate towing stone during high water.

Extensive repairs have been made to 5 model and 7 brush barges, 6 pile drivers, and 1 hydraulic grader. The hulls of these boats, except the bottoms, were nearly all repaired. Minor repairs have been made to nearly all the plant, which is requiring each year an increased expenditure for this purpose, a large number of the boats having been in service over 9 years.

The following boats and barges have been put in working condition: 5 model barges, 10 quarter boats, 2 graders, 26 skiffs, 24 brush barges, 6 general service barges, 3 steamboats, 2 mooring barges, 5 mattress barges.

To work with three revetment parties, as is proposed for this next season, will necessitate a large amount of further repair work.

SURVEYS.

Hydrographic surveys have been made in the vicinity of Lake Bolivar Front, Ashbrook Neck, Greenville, Mayersville, Raleigh, and Pilcher Point. New shore lines, showing changes in caving bends, have been located in the vicinity of Lake Bolivar from Offutts to Greenville and through Lake Providence Reach.

DISCHARGE OBSERVATIONS.

Three sets of observations for low-water discharge were taken at Wilson Point, Louisiana, in December, 1890.

A party was engaged gauging the river at Arkansas City from March 9 to May 12, 1891, and at Wilson Point from March 27 to May 7, 1891.

The results of the field observations are given in the accompanying reports of William P. Richards and John J. Hoopes.

Financial statements are herewith appended.

Very respectfully, your obedient servant,

C. McD. TOWNSEND,
Capt. of Engineers.

Gen. C. B. COMSTOCK,
Col. of Engineers, Brev. Brig. Gen., U. S. A.,
President Mississippi River Commission.

91 00	90 00

Financial statement.

LAKE PROVIDENCE REACH.

Balance, June 30, 1890		$6,526.66
Allotment, act of September 19, 1890		185,000.00
Allotment, act of March 3, 1891		330,000.00
By transfer from Levees, Fourth District		9,000.00
		530,526.66
Withdrawn	$125,000.00	
Expended to June 30, 1891	15,960.87	
		140,960.87
Balance, June 30, 1891		389,565.79
In Treasury	$358,000.00	
In hand	31,565.79	
Total balance, June 30, 1891		389,565.79
Less amounts covered by existing contracts and liabilities		30,000.00
Available balance, June 30, 1891		359,565.79
Expenditures apportioned:		
Subsistence		2,384.76
Cost of plant, repairs, and outfit		6,637.78
Care of public property		3,167.62
Towage and steamer expenses		1,682.33
Administration and office expenses		1,669.78
Surveys		290.70
Miscellaneous		127.90
		15,960.87
Amount that can be profitably expended in fiscal year ending June 30, 1893		750,000.00

VICKSBURG, MISSISSIPPI.

Balance, June 30, 1890		37,305.75
By transfer from Delta Point		156.58
Allotment, act of September 19, 1890		85,500.00
		122,962.33
Expended to June 30, 1891		38,497.93
Balance, June 30, 1891		84,464.40
In Treasury	$70,500.00	
In hand	13,964.40	
		84,464.40
Less amount covered by existing contracts and liabilities		69,464.40
Available balance, June 30, 1891		*15,000.00
Expenditures apportioned:		
Cost of plant, outfit, and repairs		421.98
Subsistence		147.42
Care of public property		675.16
Administration and office expenses		3,241.89
Dredging under contract		33,543.05
Surveys		337.43
Miscellaneous		131.00
		38,497.93
Amount that can be profitably expended in fiscal year ending June 30, 1893		100,000.00

*Reserved for repairs to Delta Point.

GREENVILLE, MISSISSIPPI.

Balance June 30, 1890		$3,482.48
Allotted, act of September 19, 1890		100,000.00
Allotted, act of March 3, 1891		100,000.00
		203,482.48
Expended to June 30, 1891		8,696.22
Balance, June 30, 1891		194,786.26
Less amount covered by existing contracts and liabilities		85,000.00
Available balance, June 30, 1891		109,786.26
In treasury		197,500.00
In hand*		
Expenditures apportioned:		
Labor on construction		449.34
Material for construction		5,763.32
Subsistence		134.85
Cost of plant, repairs, and outfit		363.50
Care of public property		1,171.58
Administration and office expenses		774.83
Miscellaneous		38.80
		8,696.22
Amount that can be profitably expended in fiscal year ending June 30, 1893		200,000.00

LAKE BOLIVAR FRONT.

Balance, June 30, 1890		20,289.72
Expended		1,619.57
Balance in hand June 30, 1891		†18,670.15
Expenditures apportioned:		
Administration and office expenses		561.67
Surveys		1,057.90
		1,619.57
Amount that can be profitably expended in fiscal year ending June 30, 1893		100,000.00

ASHBROOK NECK.

Allotment, act of September 19, 1890		300,000.00
Expended to June 30, 1891		85,038.15
Balance, June 30, 1891		214,961.85
In Treasury	$210,000.00	
In hand	4,961.85	
		214,961.85
Less amount covered by existing contracts and liabilities		85,000.00
Available balance, June 30, 1891		129,961.85
Expenditures apportioned:		
Labor on construction		28,425.27
Material for construction		42,848.45
Subsistence		6,765.84
Cost of plant, repairs, and outfit		1,676.33
Care of public property		900.00
Towage and steamer expenses		3,266.85
Administration and office expenses		477.99
Medicines and medical attendance		614.57
Miscellaneous		62.85
		85,038.15
Amount that can be profitably expended in fiscal year ending June 30, 1893		100,000.00

* $2,713.74 temporarily used from Bolivar Front allotment.
† $2,713.74 of this amount temporarily expended on Greenville, Miss., allotment.

PLANT, THIRD DISTRICT.

Allotted, act of September 19, 1890		$100,000.00
Allotted, act of March 3, 1891		30,000.00
		130,000.00
Expended to June 30, 1891		51,466.70
Balance, June 30, 1891		78,533.30
Amount covered by existing contracts and liabilities		35,000.00
Available balance June 30, 1891		43,533.30
In Treasury	$75,000.00	
In hand	3,533.30	
		78,533.30
Expenditures apportioned:		
Labor on repairs		16,865.34
Material for repairs		16,474.65
Care of plant, labor		10,284.80
Care of plant, subsistence		4,086.90
Cost of outfit and supplies		2,265.25
Administration and office expenses		1,489.76
		51,466.70
Amount that can be profitably expended in fiscal year ending June 30, 1893.		100,000.00

SURVEYS, GAUGES, AND OBSERVATIONS, THIRD DISTRICT.

Allotted, act of September 19, 1890		12,000.00
Expended to June 30, 1891		6,602.91
Balance June 30, 1891, all of which is available		5,397.09
In Treasury	$4,000.00	
In hand	1,397.09	
		5,397.09
Expenditures apportioned:		
For surveys	1,430.41	
For gauges	222.00	
For observations	4,950.50	
		6,602.91
Amount that can be profitably expended in fiscal year ending June 30, 1893.		12,000.00

LEVEES LOWER MISSISSIPPI LEVEE DISTRICT.

Allotment, act of September 19, 1890		230,750.00
Expended to June 30, 1891		141,006.01
Balance June 30, 1891		89,743.99
For protection of levees	$25,510.08	
Less liabilities	510.08	
Available balance June 30, 1891	25,000.00	
For construction of levees	64,233.91	
Less amount covered by existing contracts and liabilities	54,233.91	
Available balance June 30, 1891	10,000.00	
In Treasury for protection	12,750.00	
In hand for protection	12,760.08	
	25,510.08	
In hand for construction	64,233,91	
		89,743.99

Expenditures apportioned:			
For levee construction and repairs			$119,727.95
For engineering and office expenses			4,138.14
For high-water protection			17,139.92
			141,006.01
Amount that can be profitably expended in fiscal year ending June 30, 1893:			
For construction			1,000,000.00
For high-water protection			15,000.00

LEVEES TENSAS BASIN, THIRD DISTRICT IN ARKANSAS.

Allotment, act of September 19, 1890			237,500.00
Expended to June 30, 1891			69,282.76
Balance June 30, 1891			168,217.24
For protection of levees		$37,293.32	
Less liabilities		293.32	
Available balance June 30, 1891		37,000.00	
For construction of levees		130,923.92	
Less amount covered by existing contracts		100,923.92	
Available balance June 30, 1891		30,000.00	
In Treasury for protection	$22,500.00		
In hand for protection	14,793.32		
		37,293.32	
In Treasury, for construction	76,000.00		
In hand for construction	54,923.92		
		130,923.92	
			168,217.24
Expenditures apportioned:			
For construction of levees and repairs			44,701.32
For engineering and office expenses			4,874.76
For high-water protection			19,706.68
			69,282.76
Amount that can be profitably expended in fiscal year ending June 30, 1893:			
For construction			1,000,000.00
For protection			20,000.00

LEVEES TENSAS BASIN, THIRD DISTRICT IN LOUISIANA.

Allotment, act of September 19, 1890		129,062.00
Expended to June 30, 1891		90,153.82
Balance June 30, 1891		38,908.18
For protection (all available)	$15,533.77	
For construction (all pledged)	23,374.41	
		38,908.18
In Treasury for protection	14,062.00	
In hand for protection	1,471.77	
In hand for construction	23,374.41	
		38,908.18
Expenditures apportioned:		
For construction of levees		64,656,58
For engineering and office expenses		2,219.01
For high-water protection		23,278.23
		90,153.82

Amount that can be profitably expended in fiscal year ending June 30, 1893:

For construction	$500,000.00
For protection	15,000.00

GAUGES, THIRD DISTRICT.

Balance June 30, 1890		318.90
Expenditures apportioned:		
For pay of gauge observers	$318.00	
For stationery	.90	
		318.90

SURVEYS, EXAMINATIONS, AND INSPECTIONS.

Balance June 30, 1890		62.26
By transfer from Lake Bolivar allotment		1,000.00
		1,062.26
Expenditures apportioned:		
For pay of survey party	$510.62	
For subsistence	462.99	
For administration, inspection, and office expenses	58.65	
		1,062.26

HIGH-WATER PROTECTION OF LEVEES.

Balance June 30, 1890		747.43
Apportioned as follows:		
For material for protection	$150.83	
For fuel for steamers	128.00	
For labor	285.00	
For administration and office expenses	183.60	
		747.43

LEVEES, THIRD DISTRICT.

By amount transferred from protection of levees, fourth district		1,000.00
Expenditures, apportioned as follows:		
For labor	$690.00	
For administration and office expenses	310.00	
		1,000.00

Approximate value of plant belonging to the United States and used upon the Mississippi River, third district.

Steamboats—		Carpenter shop and outfit	$500
Osceola	$9,000	12 pile drivers and machinery	12,000
Vidalia	8,000	7 yawls	150
Meter	3,500	39 skiffs	390
Steam tug Parker	5,000	Tools and appliances	1,000
3 mattress boats	7,500	Office furniture, safe, etc	250
1 quarter boat	2,000	1 dredge (Menge)	10,000
9 quarter boats (with outfit)	8,100	2 dump scows	5,000
3 quarter boats (with outfit)	1,200	Surveying instruments	1,500
2 hydraulic graders	20,000		
24 square deck barges	19,200	Total	131,790
10 model barges	15,000		
Machine shop and outfit	2,500		

List of civilian engineers employed on work of river and harbor improvement, in charge of Capts. S. W. Roessler and C. McD. Townsend, Corps of Engineers, from May 31, 1890, to May 31, 1891, inclusive, under the river and harbor acts of August 11, 1888, September 19, 1890, and March 3, 1891.

Name and residence.	Time employed. Mos.	Time employed. days.	Compensation per month.	Where employed.	Work on which employed.
Arthur Hider, Greenville, Miss.	4		200	Greenville, Miss	Care of fleet.
	2	1	200	Ashbrook, Miss	Revetment of Ashbrook Neck.
	1	29	250	....do	Do.
	3		250	Greenville, Miss	In charge protection of and repairs to levees in Mississippi.
	1		250	....do	Repairs to plant.
H. St. L. Coppee, Vicksburg, Miss.	9		175	Vicksburg, Miss	In charge dredging operations in Vicksburg Harbor.
	3		175	Greenville, Miss	In charge enlargement of levees in Mississippi.
E. C. Tollinger, Arkansas City, Ark.	4		160	....do	Care of fleet and repairs.
	6		175	Arkansas City, Ark.	Construction and protection of levees in Arkansas.
Henry Goodrich, Lake Providence, La.	5	12	175	Lake Providence, La.	Construction of Elton Levee, Louisiana; construction of Luna, Columbia and Leland levees in Arkansas.
Jno. J. Hoopes, Arkansas City, Ark.	2		160	Arkansas City, Ark.	High-water observations and discharges.

Cost of levees in Mississippi (third district), built and enlarged by the United States from 1882 to 1891.

Year built.	Name of levee.	Built by—	Cubic yards.	Cost, including extension work.	Location on inch to mile map.
1882-'83	Magna Vista to Chotard	Mayer & Co	49,357	$10,858.54	567-570
	Shiloh to Tennessee	Arnold & Co	67,299.1	17,501.52	556-565
	Elleslie	Hugh Carlisle	133,500	27,285.12	539-541
	Skipwith	W. B. Strang & Co	71,660	13,307.18	530-531
	Longwood	....do	75,891	18,681.42	498-499
	Jenkins to Easton	James Madden	58,631	12,775.11	434-435
	Roland to Jenkins	Clay & Miller	155,159	45,520.70	424-434
	Clay & Baggotts to Roland	Fruin & Co	103,298	81,594.85	417-424
	Wade Breaks	....do	50,714	12,445.36	416
	Hughes Breaks	....do	22,882	5,491.68	403
	Beulah to Hughes	....do	152,679	43,352.94	402-403
	Beulah Enlargement	....do	66,836	22,219.93	400-402
	Beulah Breaks	Scott & Lamb	27,152	8,002.56	400
	Riverton Breaks	James T. Stokes	151,663	41,949.01	398-400
1884-'85	Riverton to Hughes	W. C. P. Jones	38,892	8,722.92	400-403
	Clay & Baggotts to Easton	L. C. Dulaney	42,560	9,765.80	417-435
1887	Ben Lomond Hoop	J. L. Perkins	44,963	7,643.71	543-544
	....do	J. P. Gray	3,218.7	708.10	544
1889	Leoto	Robert Johnson	151,260	19,663.80	511-513
	Duvalls	....do	96,084.8	30,544.96	568-569
	Greenville Front	J. A. Cannon	8,773	1,217.25	478
	Skipwith Front South	Tim Sullivan	100,146.7	14,877.99	530-570
			1,672,619.3	398,630.45	
	For protection and engineering expenses, 1882 to January 1, 1891			95,175.57	
	Total			493,806.02	

Cost of levees in Arkansas, built and enlarged by the United States from 1882 to 1891.

Year built.	Name of levee.	Built by—	Cubic yards.	Cost, including extension work.	Location on inch to mile map.
1882–'83	Duffin Break	Winters & Walsh	80,246	$21,411.68	440–442
	Panther Forest	Street & Craig	163,182	46,564.20	*449–453
1885	Arkansas City	Amos Ridge Tennessee Ind. Co.	70,039	23,569.57	425–437
1887	...do	...do	158,436.4	34,856.01	425–437
	Panther Forest	Geo. Arnold Co	302,466.3	63,611.38	451–464
	Leland Short Line	Stansell & Forrest	98,000	17,395.00	469–471
1887–'88	Amos Bayou, Arkansas City	Tapper & Fisher	123,885.4	21,060.50	427–433
	Panther Forest	W. R. Harvey	119,823.3	22,966.26	449–455
	Matthews Bend	...do	129,453	24,596.07	507–509
	Brooks Break	...do	12,566	2,261.88	507
	Leland, (lower)	L. C. Dulaney	53,128	8,500.59	485–486
	Whisky Chute	Andrews Bros	185,020.9	53,811.19	487
1888	...do	Team Force	45,000	12,769.17	487
1887–'88	Opossum Fork	Arnold & De Garis	125,923.4	31,480.84	(†)
	...do	Purcell & Greace	82,297.4	20,574.36	(†)
1888–'89	Lakeport to Louisiana line	Flynn & De Garis	106,809	20,843.47	496–521
1889	Lakeport Levee	E. Hyner	8,419.5	1,515.51	496
1888	Grand Lake	McTighe & McKee	44,509	9,791.98	509
	Sunnyside	I. M. Worthington	18,420	2,028.97	488
1888–'89	Panther Forest	W. R. Harvey	63,694.3	12,738.74	451–453
	Loops above Arkansas City	J. M. Whitehill	27,250	4,905.00	431
	Eunice, Luna, and Sunnyside	Flynn & DeGaris	120,613	21,834.91	461–490
1889	Sterling	H. W. Graves	11,748.5	1,468.52	514
	Carmichael Break	T. S. Aderholdt	5,831.6	991.37	(†)
			2,102,762	482,547.17	
	Expended for high-water protection and engineering expenses from 1882 to January 1, 1891			102,535.91	
	Total cost of Arkansas levees			585,083.08	

* Caved away.

† Not on map.

Cost of levees in Louisiana, and enlarged by the United States from 1882 to 1891.

Year built.	Name of levee.	Built by—	Cubic yards.	Cost, including extension work.	Location on inch to mile map.
1882–'83	Delta to Bedford	Hugh Carlisle	243,903.3	$62,264.07	601–606
	Sparta, above Duckport	Luke Madden	39,156.9	7,244.02	589
	Millikens Bend to Cabin Teele	John B. Reid	90,002.2	17,175.41	582–584
	Omega to Millikens Bend	Hugh Carlisle	199,059.2	42,228.81	578–581
	Raleigh to Willow Point	D. Mayer & Co	41,287.7	9,083.29	564–567
	Wilton to Raleigh	R. G. Houston & Co	390,115.8	93,930.58	561–564
	Providence	Jno. B. Reid	63,192.5	13,709.53	539–544
1884–'84	Delta to Bedford	Geo. Arnold & Co	93,062.3	17,293.86	607
	Raleigh to Willow Point	...do	126,598.2	22,811.53	564–567
1885	Wilton to Raleigh	Jos. C. Neely	13,020.5	3,615.68	561–564
			1,299,398.6	288,856.78	
	Expended for high-water protection and engineering expenses from 1882 to January 1, 1891			96,910.67	
	Total cost of Louisiana levees			385,767.45	

APPENDIX E 1.

REPORT OF WM. P. RICHARDS, SURVEYOR, ON SURVEYS AND OBSERVATIONS, THIRD DISTRICT.

On October 20, 1890, a survey party for the purpose of surveys and observations in Third District, Mississippi River was organized and placed under my charge.

During the year the following work was done.

FIELD WORK.

Hydrographic surveys have been made in the vicinity of Bolivar, Ashbrook Neck, Greenville, Mayersville, and Raleigh, in addition to the low-water survey of Lake Providence Reach.

New shore lines showing changes in caving bends have been located in the vicinity of Bolivar, from Offutts to Greenville and from Carolina to Point Lookout (Lake Providence Reach).

In all 80 miles of shore line have been located, one hundred and sixty ranges sounded, and twenty triangulation points established.

DISCHARGE.

Three sets of observations of low-water discharge was taken at Wilson Point, Louisiana.

During the high water fifteen observations were made at Arkansas City and thirty-four at Wilson Point.

The section used at Arkansas City intersects the Arkansas shore at the same point and the Mississippi shore at a point 100 feet below the section of last year.

Stations were established 300 feet apart, those next to shore being 100 feet from bank line.

The steamer *Meter* was used in the work of holding a Price current meter at the stations.

The meter was submerged six-tenths of the depth and was held by a small wire cable, having a lead of 225 pounds attached.

Soundings were taken with a cotton line, and each sounding located instrumentally.

At Wilson Point the same methods were observed.

The section used was the same as that at low water, and is 100 feet above the section of the year previous.

Results of field computations are here given.

River discharge, Mississippi River (approximate results), Arkansas City, Arkansas.

[Width main river, 3,425 feet.]

Date.	Gauge.*		Area 100 square feet.	Mean depth.	+Scour, −fill, 100 square feet.	Mean velocity per second.	Discharge, 1,000 cubic feet per second.		
	Reading.	Difference.					River.	Over bank.	Total.
1891.				Feet.		Feet.			
Mar. 9†	45.64	....	2,049	59.8	....	5.74	1,177	2	1,179
10†	45.80	+0.16	2,124	62.0	+66	5.73	1,218	2	1,220
11†	46.08	+0.28	2,100	61.3	−33	5.42	1,139	3	1,142
12‡	46.36	+0.28	2,174	63.5	+64	5.21	1,132	3	1,135
13‡	46.53	+0.17	2,191	64.0	+11	5.32	1,165	3	1,168
14‡	46.65	+0.12	2,170	63.4	−25	5.36	1,163	4	1,167
16‡	46.88	+0.23	2,192	64.0	+15	5.49	1,204	4	1,208
17‡	46.93	+0.05	2,203	64.3	+ 8	5.49	1,211	4	1,215
18‡	47.00	+0.07	2,211	64.5	+ 5	5.35	1,183	4	1,187
19‡	47.13	+0.13	2,201	64.3	−14	5.26	1,157.5	4.5	1,162
20‡	47.26	+0.13	2,272	66.3	+66	5.16	1,171	5	1,176
21‡	47.34	+0.08	2,245	65.6	−29	5.34	1,198	5	1,203
22‡	47.45	+0.11	2,304	67.3	+55	5.35	1,233	5	1,238
23‡	47.49	+0.04	2,309	67.4	+ 4	5.26	1,215	5	1,220
24‡	47.55	+0.06	2,345	68.5	+33	5.40	1,265	5	1,270

* Arkansas City gauge. † Meter used, Price No. 5. ‡ Meter used, Price No. 6.

River discharge, Mississippi River, (approximate results), Wilson Point, Louisiana.

[Width. 3,790 feet.]

Date.	Gauge.		Area 100 square feet.	Mean depth.	+ Scour, − fill, 100 square feet.	Mean velocity per second.	Discharge, 1,000 cubic feet per second.		
	Reading.	Difference.					River.	Over bank.	Total.
1891.				*Feet.*		*Feet.*			
Mar. 27*	40.66	....	2,135	56.2	....	5.77	1,232	16	1,248
28*	40.74	+0.08	2,177	57.4	+39	5.78	1,259	19	1,278
30*	40.85	+0.11	2,172	57.3	− 9	5.86	1,273	20	1,293
31*	40.89	+0.04	2,218	58.5	+44	5.58	1,237	21	1,258
Apr. 1*	40.93	+0.04	2,233	58.9	+13	5.62	1,256	22	1,278
2*	40.98	+0.05	2,243	59.2	− 8	5.81	1,303	22	1,325
3*	41.00	+0.02	2,219	58.5	−25	2.50	1,324	22	1,346
4*	40.90	−0.10	2,217	58.5	+ 2	5.89	1,306	22	1,328
6*	40.82	−0.08	2,230	58.8	+16	5.66	1,262	21	1,283
7*	40.79	−0.03	2,249	59.3	+20	5.70	1,281	20	1,301
8*	40.74	−0.05	2,267	59.8	+20	5.47	1,239	19	1,258
10*	40.61	−0.13	2,244	59.2	−18	5.62	1,262	18	1,280
11*	40.51	−0.10	2,283	60.2	+43	5.48	1,250	17	1,267
13*	40.30	−0.21	2,246	59.3	−29	5.55	1,247	17	1,264
14*	40.24	−0.06	2,229	58.8	−15	5.62	1,253	16	1,269
15*	40.17	−0.07	2,240	59.1	+13	5.49	1,229	16	1,245
16*	40.08	−0.09	2,245	59.2	+ 7	5.49	1,232	15	1,247
17*	40.01	−0.07	2,242	59.1	....	5.41	1,213	15	1,228
18*	40.00	−0.01	2,231	58.9	−11	5.24	1,169	14	1,183
20*	39.92	−0.08	2,228	58.8	....	5.24	1,169	14	1,183
21*	39.87	−0.05	2,240	59.1	+14	5.25	1,176	13	1,189
22*	39.86	−0.01	2,271	59.9	+31	5.10	1,158	13	1,171
23*	39.86	....	2,303	60.8	+32	5.13	1,181	13	1,194
24*	39.86	....	2,350	62.0	+47	5.37	1,166	13	1,179
25*	39.91	+0.05	2,352	62.1	....	4.91	1,154	14	1,168
27*	40.04	+0.13	2,332	61.5	−25	5.00	1,166	15	1,181
28*	40.06	+0.02	2,328	61.4	− 5	5.01	1,168	15	1,183
29*	40.01	−0.05	2,324	61.3	− 2	5.10	1,184	15	1,199
30*	39.91	−0.10	....	....	....	....	....	....	....
May 1*	39.78	−0.13	2,241	59.1	....	5.17	1,158	10	1,168
2†	39.59	−0.19	2,241	59.1	+ 7	5.15	1,155	7	1,162
4†	39.01	−0.58	2,217	58.5	− 2	5.12	1,136	7	1,143
5†	38.63	−0.38	2,219	58.5	+16	4.98	1,106	5	1,111
7†	37.24	−1.39	2,200	57.9	+84	4.55	999	3	1,002

* Meter used, Price No. 6. † Meter used, Price No. 5.

Gauge at section referred to datum of Wilson Point Gauge.

Discharge measurements, Mississippi River, Wilson Point, Louisiana.

[Width, 3,645 feet.]

Date.	Gauge.		Area.	Mean depth.	+Scour −Fill.	Mean velocity per second.	Discharge per second.
	Reading.	Difference.					
1890.			*Square ft.*	*Feet.*	*Square ft.*	*Feet.*	*Cubic ft.*
Dec. 28*	10.03	−0.30	78,483	21.5	....	3.328	261,178
29*	9.93	−0.10	79,097	21.7	+ 982	3.373	266,805
30*	10.25	+0.32	78,830	21.6	−1,433	3.334	262,806

* Meter used, Price No. 5.

OFFICE WORK.

Maps have been plotted from the original notes and tracings made of the following surveys:

Bolivar surveys, Greenville Bends, Bachelor Bend surveys, upper dikes in Greenville Harbor, Hydrographic survey of Lake Providence Reach (low water), shore line survey of Lake Providence Reach (high water), and Raleigh survey.

Approximate results of discharge observations taken at Arkansas City and Wilson Point have been computed by method of partial discharge, the areas being obtained by taking depths at quarter stations.

CAVING BENDS.

Bolivar.—A shore-line survey was made in this vicinity in October, 1890, and a hydrographic survey in May, 1891. Both surveys show caving to exist from the lower end of revetment work to Buck Ridge Landing, a distance of 1¼ miles. About half way between these points the caving is greatest, amounting to 700 feet in 2 years.

Georgetown Bend.—In this bend caving extends from Offutt to Ashbrook Point, a distance of 5 miles. Just below the new revetment the bank has receded from 300 to 400 feet during the past year, and Ashbrook Neck has been narrowed to 2,150 feet.

Rowdy Bend.—Caving continues from one-half mile below Gaines Landing to Point Comfort, distance 5¼ miles.

In the sharpest part of the bend the river has approached 200 feet nearer to Panther Forest Levee, and is now within 650 feet of the levee.

Miller Bend.—Very little change has taken place during the past year. At the narrow part of Tarpley Neck the bank remains about the same.

Spanish Moss Bend.—Just below Linwood, and at small stretches along Point Chicot, has occurred some slight caving.

Bachelor Bend.—Caving extends from 1 mile above Barnes Landing to Davies Street, Greenville; distance, 3 miles. In the vicinity of Barnes Landing the caving averages 300 feet a year.

Just above Greenville the river has scoured out the bank behind the upper dikes, the extent of the caving at places amounting to 900 feet.

Lake Providence Reach.—On Island 89 and on Sarahs Island near the head of the reach, caving has been very slight during the past year.

In Louisiana Bend most of the caving is taking place 2 miles below Pilcher Point Landing, where the change has been 600 feet the past year. On Island 92 caving continues, and the bank lines of Skipwith Towhead are 1,000 feet farther in than the lines of the previous year.

At Wilson Point, at Mayersville, and at Clover Hill caving has ceased. Just below Homochitto Landing changes are going on, and much of the dike work at the head of the Baleshed system is being washed away.

In the bend from Longwood to Providence, a distance of 4 miles, it continues to cave at the rate of 600 feet a year with the point of maximum caving moving down the river.

At Shipland Point and at Ajax Bar changes have been great; the latter has almost disappeared, and the current will soon be against the Louisiana shore in that locality.

APPENDIX E 2.

REPORT OF MR. JOHN J. HOOPES, ASSISTANT ENGINEER, ON DISCHARGE OBSERVATIONS AT ARKANSAS CITY.

These observations from March 25 to May 12, are the continuation of a series begun by W. P. Richards, United States Surveyor, who was transferred to Wilson Point, La.

The velocities were taken with current meter at 0.6 depth, and the revolutions indicated by a telegraphic sounder.

Observations of 5 or more minutes were taken at each of 12 stations, and the revolutions during each minute were recorded. The soundings for the cross section were instrumentally located.

The width of the section was 3,427 feet.

The steamer *Vidalia* was used in the work.

METERS.

Price meters Nos. 4, 5, and 6 were used. No. 4 was used on March 25, 26, and 27, while No. 5 was being repaired, and again on May 2, 4, 6, and 7, while No. 5 was being exchanged for No. 6.

On May 4 an insulator was taken out of No. 4 so that revolutions instead of half-revolutions were indicated by the sounder and the bearings were thoroughly cleaned. The observations that followed were quite satisfactory, but the ratings and the ob-

servations previously taken with it, were so discordant that no results are given for them in tabulated statements accompanying this report.

No. 5 meter was used from March 28 to April 30, but as the result of the field computations showed a much larger discharge here than at Wilson Point, this meter was taken there and compared with and exchanged for No. 6, which had been in use there.

The latter was received on May 7 and used to the end of the series. A direct comparison was made between meters Nos. 5 and 6, on a section of the river near Greenville, on May 14, by placing both meters on the same cord 2 feet apart and counting their revolutions simultaneously. Eight observations of 5 minutes each were made in which No. 6 made 0.01 less revolutions than No. 5. The positions were interchanged and seven more observations were then made over the same section and in these No. 6 made 0.09 more revolutions than No. 5.

The values used in computing the discharge from the observations in which No. 5 was used were obtained by a combination of ratings at various times by different observers, as given in the following table:

Date.	Authority.	No. of observations.	Base.	Rating.		Place.	Remarks.
				a	*b*		
1890.							
Feb. 26	Fred P. S.	24	200	3.765	.253	Wilson Point	Running water.
Apr. 11	Fred P. S.	29	200	3.791	.204	....do	Still water.
1891.							
Jan. 19	Wm. P. R.	32	200	3.772	.203	Greenville	Running water.
Mar. 28	J. J. H.	13	400	4.050	.142	Huntington	Still water.
Apr. 14	J. J. H.	14	400	4.130	.027	....do	Do.
May 3	W. P. R.	40	200	3.733	.310	Wilson Point, Louisiana.	Do.

The values of a and b in each were weighed by the product of the number of observations by the length of base.

This gives the value of $y = 3.862 + .197$.

OTHER SOURCES OF ERROR.

To test the soundings made with cotton line, one-half of the section on April 25, and all except near the banks on the 27th and 28th, were also measured by drifting soundings with a 15-pound lead attached to a graduated piano wire and raised and lowered by a reel.

The sections with the cotton line were as follows: 25th, 1.5 per cent. less; 27th, 0.8 per cent. greater; 28th, 0.3 per cent. greater.

Surveys of the direction of the current were made on May 1 and 5 by floating a 14-foot rod submerged 12 feet and instrumentally determining its position when crossing range lines 255 feet above, and 308 feet below the discharge section.

Each of these surveys showed 2 per cent. increase of velocity due to this cause. The lateral motion of the boat was estimated on May 9 and 12, and the computations from these figures showed a probable average of about 0.5 per cent. increase of velocity due to this cause.

The observations for station 2 were not taken at its proper location prior to April 21, but this fact was disregarded in the first computations, thus making the discharge about .01 too great. A reduction of .02 was made in the velocities as an allowance for these various small errors.

GAUGE READINGS.

The gauge readings given are those of the standard gauge at the elevator on right bank 2,570 feet above the discharge section, and were read at the close of each observation, the readings being immediately preceded by the soundings for the cross section.

Other readings of this and other gauges were recorded, but are not given in this report.

OVERFLOWED BANKS.

In measuring the discharge over banks the velocities were measured with the meter and the distances by stadia measurements.

The widths of the section were:

	Feet.
On right bank	260
On left bank via an old levee	1,190

The maximum discharge was about 8,000 cubic feet per second.

AMOS BAYOU DISCHARGE.

The volume of water passing around the end of the levee at Amos Bayou as obtained by Assistant Engineer Tollinger, on March 28, was 5,000 cubic feet per second. A table of the results of these observations is appended.

Discharge observations at Arkansas City.

Date.	Gauges.		Area, 100 square feet.	+Scour and −fill, 1,000 square feet.	Mean velocity per second.	Discharge, 1,000 cubic feet per second.		
	Reading.	Difference.				River channel.	Over banks.	Total.
1891.					Feet.			
Mar. 25*	47.70	....	2,367	....	....	....	....	....
26*	47.72	+0.02	2,410	+42	....	....	....	....
27*	47.82	+0.10	2,367	−56	....	....	....	....
28†	47.84	+0.02	2,376	+18	5.72	1,359	7	1,366
30†	47.90	+0.06	2,360	−18	5.73	1,352	7	1,359
31†	48.02	+0.12	2,370	+06	5.83	1,382	7	1,389
Apr. 1†	48.10	+0.08	2,362	−10	5.67	1,339	8	1,347
3†	48.16	+0.06	2,386	+11	5.64	1,346	8	1,354
4†	48.20	+0.04	2,372	−15	5.64	1,338	8	1,346
6†	48.19	−0.01	2,378	+06	5.62	1,336	8	1,344
7†	48.16	−0.03	2,401	+24	5.67	1,361	8	1,369
8†	48.10	−0.06	2,358	−40	5.65	1,333	8	1,341
9†	47.99	−0.11	2,345	−10	5.75	1,348	7	1,355
10†	47.90	−0.09	2,343	+01	5.58	1,307	7	1,314
11†	47.82	−0.08	2,359	+19	5.49	1,295	6	1,301
13†	47.59	−0.23	2,317	−33	5.39	1,249	5	1,254
14†	47.49	−0.10	2,349	+35	5.47	1,285	5	1,290
15†	47.42	−0.07	2,344	−03	5.32	1,247	5	1,252
16†	47.31	−0.11	2,355	+15	5.38	1,267	4	1,271
18†	47.24	−0.07	2,323	−30	5.32	1,236	4	1,240
20†	47.20	−0.04	2,326	+05	5.23	1,216	4	1,220
21†	47.17	−0.03	2,321	−03	5.36	1,244	4	1,248
22†	47.13	−0.04	2,288	−33	5.23	1,197	4	1,201
23†	47.10	−0.03	2,315	+28	5.29	1,225	4	1,229
24†	47.16	+0.06	2,320	+03	5.29	1,227	4	1,231
25†	47.29	+0.13	2,311	−14	5.30	1,225	4	1,229
27†	47.47	+0.13	2,255	−62	5.41	1,220	4	1,224
28†	47.42	−0.05	2,288	+35	5.43	1,242	4	1,246
29†	47.33	−0.09	2,200	−25	5.29	1,196	4	1,200
30†	47.15	−0.18	2,253	−01	5.24	1,181	4	1,185
May 2*	46.50	−0.65	2,240	+09	....	....	3	....
4*	45.62	−0.88	2,264	+54	4.88	1,105	2	1,107
6*	43.87	−1.75	2,141	−63	4.67	1,000	1	1,001
7*	43.00	−0.87	2,101	−10	4.58	962	....	962
8‡	41.72	−1.28	2,080	+22	4.41	917	....	917
9‡	40.53	−1.19	2,035	−04	4.23	861	....	861
11‡	38.22	−2.31	1,981	+25	4.13	818	....	818
12‡	37.05	−1.17	1,912	−29	4.10	784	....	784

* Metre used, Price No. 4. † Metre used, Price No. 5. ‡ Metre used, Price No. 6.

APPENDIX E 3.

ESTIMATE OF MR. HENRY B. RICHARDSON, CHIEF STATE ENGINEER, LOUISIANA, FOR LEVEE CONSTRUCTION IN LOUISIANA FROM STATE LINE TO WARRENTON.

STATE OF LOUISIANA, BOARD OF STATE ENGINEERS,
New Orleans, June 5, 1891.

DEAR SIR: I herewith submit for your information the following list, which gives the approximate amount of work required to place the levee line along the Tensas Front in Louisiana, between the Arkansas line and opposite Warrenton, on a reasonably secure basis, viz, raising the grade of existing levees from the present land edge

of crown with a 3 to 1 slope to 3 feet above high water of 1890, and giving an 8-foot crown, with a 3 to 1 slope on river side; and constructing new levees where the present line is threatened by caving river banks, to a grade of 3 feet above high water, with an 8-foot crown, and side slopes of (3 and 3) 6 to 1.

Location.	Length.	Approximate.	Remarks.
	Feet.	*Cubic yds.*	
Arkansas line to Pilcher Point	29,900	167,440	
Bunches Bend	49,700	300,000	
Bunches Bend to Wilson Point	9,530	....	Repaired, 1890.
Wilson Point Levee	8,009	....	Built in 1890.
Wilson Point to Longwood	27,980	122,960	
Longwood to New Elton	7,152	19,301	
New Elton Levee	18,500	....	United States contract.
New Elton to Hagaman	12,900	50,310	
Hagaman to Wylie	8,600	33,540	
Wylie to Point Lookout	9,000	....	Repaired, 1890.
Do	19,400	150,000	
New Concord Levee, 1891	3,329	....	District contract.
Point Lookout to Wilton	27,600	227,000	
Wilton to Goodrich	12,600	....	Repaired, 1890.
Goodrich to Pecan Grove Levee, new location	18,500	592,000	Caving banks, wave wash, 1891.
Pecan Grove Levee of 1890	15,800	25,500	
Pecan Grove to Mascot	24,350	170,450	
Mascot to Omega Landing	10,900	40,600	
Omega to Milliken Bend	10,800	9,000	Repaired, 1890.
Do	7,300	47,000	
Milliken Bend to Cabinteele, new location	21,900	464,000	Caving banks.
Cabinteele to Jeffries Landing	26,982	35,000	
Jeffries Landing to Elcho	18,500	38,000	
Elcho Levee	2,100	....	Built in 1890.
Elcho to Delta	17,400	12,743	
Delta to Bedford	8,674	....	Repaired, 1890.
Do	35,213	300,000	
Total	462,119	2,795,844	

87.5 miles.

To increase the land side of present line to a uniform slope of 3 to 1 it will require about 700,000 cubic yards additional; and to add a 20-foot banquette on land side, with its top 10 feet below grade line, it would require about 500,000 cubic yards.

In this list I assume that the Elton Levee, now under contract by the United States Engineers, and the Concord Crevasse Levee, now under contract by the Fifth Louisiana Levee District, are provided for.

The Fifth District also has some stretches of raising and enlargement under contract, but at present we do not know of their financial ability to perform the work; so we consider them as required.

Yours, most respectfully,

HENRY B. RICHARDSON,
Chief State Engineer.

Capt. CURTIS McD. TOWNSEND,
Corps of United States Engineers.

APPENDIX E 4.

REPORT OF CAPTAIN WILLIAM T. ROSSELL, CORPS OF ENGINEERS, UPON A LINE TO CONNECT ARKANSAS RIVER AND MISSISSIPPI RIVER LEVEES.

UNITED STATES ENGINEER OFFICE,
Memphis, Tenn., July 15, 1889.

GENERAL: I have the honor to submit the following report on a levee line to connect the Arkansas River system of levees with the Mississippi River system south of the Arkansas River. At a meeting of the Mississippi River Commission held on December 3, 1888, the following resolution was adopted:

Judge Taylor moved the following:

"*Resolved,* That Captain Rossell be directed to make a survey of a line of levees along the south bank of the Arkansas River to a point where it can be tied to the

nearest high lands or joined to existing levees, and to report to the Commission his judgment as to the value of such a line of levees as a means of lowering the flood heights at the head of the Tensas Basin, with any facts within his knowledge bearing on that subject, the cost of the survey to be paid out of the allotment for surveys, third district, made December 2, 1888."

Carried.

The area in which this survey is to be made is called the Arkansas Basin, and forms the lower part of the White and Arkansas Basin, which is described on the Commission map of the alluvial valley of the Mississippi River as extending from Helena to Arkansas City. Below Arkansas City the lowlands subject to overflow are called the Tensas Basin. The dividing line between these two basins is indefinite, and although from the map it would seem to be an east and west line through Arkansas City, yet in building levees, and in many of the reports on levees, the line from the bank of Amos Bayou along the south line of Cypress Creek is spoken of as the head of the Tensas Basin. I believe this resolution refers to this line, and it is to determine whether the building of the line of levees spoken of would reduce the flood plane at and strain on these levees that the survey was called for. My understanding of the resolution is as follows: That I am required to make a survey for the line of levees, and to report to the Commission my judgment as to the value of such a line as a measure of lowering the flood heights along the present levees from Amos Bayou to Arkansas City. If reference is made to the Commission map of the alluvial valley of the Mississippi River it will be seen that the lowland in which this levee stands is subject to overflows from floods in the White, Arkansas, and Mississippi rivers. The area inclosed between the Arkansas River, Mississippi River, the lowlands, and the levee is about 250 square miles. This area is drained during the lower stages of the river by the Arkansas River along its northern border, and Cypress Creek along its southern border. During the overflow of 1887, the only one that has come under my own eye in which the swamp was well filled, the water reached its highest level near where the levee crosses Boggy Bayou, and then flowed in both directions, part into the Mississippi through Cypress Creek, and part overflowing the banks of Amos Bayou flowed down through the back bayous and lakes into Red River. It may here be remarked that the 1887 flood was the highest on record along the Opossum Fork Levee.

The overflows of 1887 and 1888 are the only ones that have occurred since I have been in charge of the district, and in both cases no great trouble was caused by the Arkansas River.

A great rise coming out of this river during a flood from the Mississippi would make changes which, however, I believe can be predicted with some certainty. During the overflows of 1887 and 1888 the water began rising against the levee as soon as the Mississippi got out of its banks, but Cypress Creek carried off this water so fast that the rate of rising along the levee was about one-half what it was in the main river. As the flood increased, Cypress Creek became gorged, and the water along the levee rose more and more rapidly, reaching at one time twice the rate in the main river. As the wave reached its crest in the main river this ratio decreased, and finally the water reached its greatest height along the levee and in the main river almost at the same time. The flood of 1887 reached 46.65 feet on the Arkansas City gauge, and in 1888, 45.2 feet. This difference, about 1¼ feet, represents the difference in the main river, yet along the upper part of this levee the difference in these years was 3¼ feet. Had the Arkansas River poured out a great flood at the time of the Mississippi River overflow in 1887, it would seem probable that Amos Bayou would have been filled up, and the summit level of the water would have been higher and farther inland than Boggy Bayou at the levee crossing. The Arkansas River is subject to sudden and violent rises coming at nearly all seasons of the year, yet in the majority of overflows the Mississippi River is the controlling element. This being so, to get the best effect from a line of levees connecting with the Arkansas River system, the line should connect with the present Mississippi River system nearer the Mississippi River than the Boggy Bayou crossing. The above facts were known before any survey was made, and an examination showed that no line could be built connecting the Arkansas River levees with high land that would have any effect in this way. The question then reduces itself to surveying a line to connect the Arkansas River and the Mississippi River systems of levees, the point of junction being no farther from the Mississippi River than the present Boggy Bayou crossing. An examination of the map will show that this can not be done without crossing Cypress Creek, and thereby destroying the drainage of a considerable part of the low land lying between it and the Arkansas River. Still, I believe that a line of levees terminating on the north bank of Cypress Creek would fill the spirit of the resolution, and ordered the survey made. The nearer to the Mississippi River this junction of creek and levee is made the greater will be the effect in lowering the flood plane along the Opossum Fork Levee. At the time of the passage of this resolution all levee work was being pushed as rapidly as pos-

sible, and high water might be expected at any time. For this reason the survey was put off. On March 13, 1889, steps were taken to organize and put into the field a survey party. The survey was intrusted to Assistant Engineer Henry Goodrich, and field work began on April 10, 1889, and was finished May 17, 1889. Since this time the calculations have been made and other work done. The survey was carefully made, and I believe the estimates can be relied on for making contracts should the work be ordered by the Commission.

The lines of levees surveyed were two, which for convenience are called the front line and the swamp line. The front line begins about 18 miles above the mouth of the Arkansas River near Yancopin plantation, and follows near the river for a distance of nearly 16 miles. It then leaves the Arkansas River and crossing the neck of Caulks Point, comes out on the bank of Cypress Creek near its mouth. The swamp line starts at the same place, but leaves the Arkansas River levees about 11 miles from the starting point, crosses the swamp, and comes out on the bank of Cypress Creek near the Boggy Bayou crossing. Above the starting point the Arkansas River levees are said to be in good condition for about 25 miles. As there was no reliable data to be obtained as to the high water along this line, mud marks were used. To determine the highest points on the trees thus marked, the bank was cut into and careful examination made for traces of sand and sediment left by past floods. The grade of the levee was then placed $3\frac{1}{2}$ feet above this. On closing with the present Opossum Fork Levee, it was found that the grade agreed closely with the grade ordered by the Commission for this levee, viz, 3 feet above the highest known high water. The cross section assumed is 8 feet crown and one-third slopes front and rear. The estimates for the two lines are as follows:

Front line, 1,621,198 cubic yards, at 20 cents	$324,239.60
Swamp line, 1,249,800 cubic yards, at 20 cents	249,960.00

I am of the opinion that the building of the swamp line will have but little effect in lowering the flood line along the Opossum Fork Levee, except in years where the Mississippi River overflow is augmented by a great flood from the Arkansas River, and in this case perhaps a maximum effect of 2 foot might be obtained. However, this line of levee might be effective in lowering the flood line along Amos Bayou from the end of the Opossum Fork Levee to the high land. I am of the opinion that this is not a matter of great importance, as, with the Tensas Basin closed below, the bayous and lakes back of the river can take care of all the water flowing through Amos Bayou.

I am of the opinion that the building of the front line will lower the flood line along all of the Opossum Fork Levee from Lucca Landing, near the mouth of Cypress Creek, to the high land. The water along the levee will then be merely water backed up Cypress Creek, and can nowhere reach a higher stage than at the mouth of the creek. In the flood of 1887, the high-water line would have been reduced near Boggy Bayou crossing nearly $4\frac{1}{2}$ feet had this front line been in existence.

I am not required to examine into any other question than the effect of the building of this line in lowering of the flood line along the head of the Tensas Basin, and have consequently confined myself to it.

Very respectfully, your obedient servant,

WM. T. ROSSELL,
Captain of Engineers.

Gen. C. B. COMSTOCK,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

APPENDIX F.

REPORT OF FIRST LIEUTENANT JOHN MILLIS, CORPS OF ENGINEERS, UPON OPERATIONS IN THE FOURTH DISTRICT.

UNITED STATES ENGINEER OFFICE,
New Orleans, La.

SIR: I have the honor to submit the following report upon the works in charge of this office under the Mississippi River Commission for the year ending June 30, 1891:

In obedience to Special Orders, No. 202, dated Headquarters of the Army, A. G. O., August 29, 1890, I reported here for duty on October 11, 1890, and Capt. Dan C. Kingman, Corps of Engineers, U. S. Army, whom I was ordered to relieve, after visiting with me all the various works of the district, left for his new station on November 4, 1890.

IMPROVEMENT OF THE MISSISSIPPI RIVER AT NATCHEZ, MISSISSIPPI, AND VIDALIA, LOUISIANA.

The project for this improvement, which was adopted after the transfer of the work to the Mississippi River Commission, contemplated the protection of caving banks by submerged sloping spur dikes and the construction of a levee to prevent the flow of water at high stages of the river across the narrow neck above Natchez.

The estimated cost of this work was $760,000.

No construction work was ever done under this project owing to insufficient funds.

At its meeting of November 26, 1890, the Commission directed that a resurvey of the bank line in the vicinity of Natchez be made extending from the head of Giles Bend to just below Vidalia, that three or four typical cross sections be sounded near the apex of each bend, that a line of levels be run across the narrow neck between Giles and Cowpen bends, and that a report be submitted to the president of the Commission showing what improvements are required in this vicinity.

For making this survey the additional sum of $1,500 was allotted, and there was on hand at the time unexpended a balance from previous allotment of $675.65.

The survey has been completed and the report submitted as directed by the Commission.

IMPROVING MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA, MISSISSIPPI AND LOUISIANA.

Money statement.

July 1, 1890, balance unexpended	$675.65
June 30, 1891, amount expended during fiscal year	675.65
Amount that can be profitably expended in fiscal year ending June 30, 1893	250,000.00
Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.	

WORKS OF IMPROVEMENT AT THE JUNCTION OF THE MISSISSIPPI, RED, AND ATCHAFALAYA RIVERS, LOUISIANA.

RECTIFICATION OF THE RED AND ATCHAFALAYA.

The conditions of the river channels in this vicinity are somewhat peculiar and confusing. In the following brief description the terms used differ in some respects from those employed in previous reports, in order to conform more nearly to the present state of affairs and with the object of making the situation clearer to persons unfamiliar with the locality as it is at present or with the conditions as they existed in former times.

The Red and Atchafalaya may now be regarded as constituting really one river, which for the purposes of this description will be called the ***Red-Atchafalaya.*** In the vicinity under consideration this river has a general direction parallel to that of the Mississippi, and approaches it at Turnbull Island on the western shore to within a distance of about 6 miles. This point of near approach to the Mississippi is also the point of division between that part of the first-mentioned river which is usually called the Red and that part to which the name Atchafalaya is applied. At Turnbull Island there is a connecting link between the Mississippi and the Red-Atchafalaya which is known by the general name of Old River. This connection starts from the Mississippi about a mile above Red River Landing, at a point which is sometimes referred to as the "Mouth of Red River," and divides into two parts or branches about 1¼ mile from the Mississippi. One branch, called Lower Old River, goes direct to the Red-Atchafalaya south of Turnbull Island, and the other, called Upper Old River, passes around the north side of the island and also unites with the Red-Atchafalaya 2 miles above the point where Lower Old River comes in; but before reaching the Red-Atchafalaya the Upper Old River subdivides at a point about 1¾ miles from its western end into three smaller branches called Straight Chute, Middle Chute, and Sugar House Chute, respectively.

The channel distance from the Mississippi through Lower Old River to the Red Atchafalaya is about 7 miles, and by way of Upper Old River the distance would be about 9 miles.

Turnbull Island was formerly a long neck or peninsula of land in a bend of the Mississippi and on the eastern bank, and the island was formed by a cut-off intentionally made in 1831 with a view to channel improvement. The connecting branches just described as well as that portion of the Red-Atchafalaya included between

their western extremities, now occupy, although they by no means fill, an old bed of the Mississippi River; hence the term "Old River."

This description is not absolutely correct for all stages of the water, since in low water the bed of Upper Old River is dry and the same is occasionally true at certain points in Lower Old River, as will be referred to later on; while during flood a good portion of the surrounding country, being low and unprotected by levees, is under water.

Under favorable conditions Lower Old River constitutes a navigable connection between the Mississippi and the Red-Atchafalaya, and accommodates a very important river commerce, but the conditions are at present subject to such changes as to cause at times serious deterioration and even complete interruption of this connecting link between these two great river systems.

In order to properly maintain a navigable depth in any sediment-bearing water way of considerable length a current is manifestly essential, since without a flow of the water of sufficient velocity to keep the channel clear a deposit of sediment and filling up of the water way will occur.

The direction and force of the current in the branches of Old River will evidently depend upon the relative height of the water in the Red-Atchafalaya and Mississippi, and according as the one or the other of these two rivers happens to be the higher, or as they are both at the same level, the current through Old River is towards the east, towards the west, or is nil. In the first case there is a greater or less discharge from the Red-Atchafalaya system into the Mississippi; or otherwise stated, Red River proper has then two outlets or branches, one through the Atchafalaya and one into the Mississippi, while the discharge of the Mississippi is confined entirely to its own channel.

In the second case the discharge of the Red-Atchafalaya is confined to its own channel, while a portion of the water of the Mississippi is diverted from that river and passes down the Atchafalaya.

In the third case the two river systems are independent so far as their discharge is concerned, and the conditions of discharge are then practically the same as would be the case if no connection existed.

During floods the state of affairs as above described has often been greatly modified by the giving way of the levees on the Tensas Front of the Mississippi River and elsewhere, but the levee system on the Mississippi has now been so far completed that this element of complication may be regarded as practically removed from the problem.

The condition of absolutely no current in the connecting link is comparatively rare, but the current is frequently so slight that sufficient deposit occurs to seriously interfere with navigation, and during the low-water season the connection has at times entirely been severed. Moreover the unfavorable conditions are aggravated no doubt by the division of the connecting channel, since when a current does exist at medium and high stages the effect in clearing out the channel is weakened by this division.

The value of the commerce of the entire Red-Atchafalaya system was estimated in 1887 to be about $40,000,000 annually. For the low-water period, during which the difficulty in Old River occurs, the mileage of navigable river is of course greatly reduced, but even then a temporary interruption of this connection with the Mississippi is a serious damage since the system has no practicable outlet of its own, and no other connection with the Mississippi system, while the permanent closure of the connection would involve a loss to commercial interests and to the community in general which would justify a very large expenditure to prevent.

The general object of the works of improvement now in progress is to rectify the defects above outlined, and it is proposed to effect this by causing a separation of the Red from the Atchafalaya at Turnbull Island for all stages of these rivers below medium low water (about 10 feet above extreme low water), making the Red a proper tributary to the Mississippi when it is at or below this stage, while the Atchafalaya becomes at the same time an outlet or "diffluent" of the Mississippi. The plan also contemplates preventing any further enlargement of the Atchafalaya or any detrimental effect on the channel of the Mississippi due to the action of the Atchafalaya as an outlet or diffluent stream, and the whole work is designed to have no material effect on the high-water régime of the various rivers involved, and to produce no greater danger of injury to property from overflow than now exists.

This general project contemplates the following work: A series of low relief dams or sills not to exceed 6 in number, to be built in the Atchafalaya proper at intervals of about a quarter of a mile. These dams to be located below the mouth of Bayou Des Glaise, near Simmsport, about 5 miles below Turnbull Island. These dams are designed to prevent further enlargement of the Atchafalaya and to limit its discharge capacity. They are to be built up of successive layers of mattresses made of willow brush and timber, ballasted with stone and intervening layers of mixed gravel and clay. The foot mattress to have a width up and down stream of about 300 feet, and

the maximum depth over the crest of the dam to be about 7 feet at extreme low water. The high-water discharge over these dams is intended to be equal to the flood discharge of Red River proper, or about 200,000 cubic feet per second.

A dam is also to be built across the river from the west side of Turnbull Island to the main land. This dam to be constructed of successive layers of willow and timber mattresses with stone ballast, its crest to be about 10 feet above low water and its top and side slopes to be heavily paved with rock. The foot mattress has a maximum width up and down stream of 280 feet. The total length of the dam proper is 1,125 feet, and of the shore-protecting mattresses about 2,700 feet. The maximum height of the dam is 27 feet.

This dam effects the separation of the Red from the Atchafalaya at all stages of the water below the level of its crest and deflects Red River through Sugar-House Chute and Upper Old River. To complete the separation of the Red from the Atchafalaya a canal is to be cut from Upper Old River across Carr Point to the Mississippi, and a dam or obstruction is to be built to close Upper Old River below the canal at some point opposite the eastern end of Turnbull Island.

To secure a navigable channel through Upper Old River it is to be deepened by dredging or otherwise, as may be found most expedient.

During the progress of the above work an attempt is to be made to temporarily maintain navigation through Lower Old River by dredging, washing the bottom with steam tugs, or by other expedients.

Up to the time of the last Annual Report the following work had been accomplished:

Two of the sill dams in the Atchafalaya, Nos. 1 and 3, had been completed and the sill or foot mattress and shore protection of the dam at the head of Turnbull Island, usually referred to as the Red River Dam, had been completed. The temporary work of dredging, scouring, etc., to keep the channel in Lower Old River open during low water, had also been resorted to with more or less success whenever necessary.

There had been expended on the work up to that date since its charge was assumed by the Mississippi River Commission the sum of $413,768.57, but the improvement had not reached such a stage as to have any direct effect in increasing the depth in Lower Old River, the immediate object of the portion of the work first undertaken being to check further deterioration of that channel.

At the beginning of the year the value of material for construction on hand was $22,692.82, and there was a balance from former appropriation of $23,731.63.

Repairs to the plant were then in progress. They were completed early in the season, and the first work undertaken was dredging in Lower Old River to keep the channel open during low water. Though the water went down to 2¼ feet for a few days in August, the channel was not closed entirely at any time during the season, 6 steamers having passed through at the lowest stage, but they required the aid of barges belonging to the fleet which were used as lighters, so it can hardly be said that a navigable channel was maintained, though the interruption was of only a few days' duration.

An allotment of $225,000 was made for this work from the appropriation of September 19, 1890, and in obedience to instructions from the president of the Commission the following project was submitted for continuing the improvement on November 19, 1890:

"It is proposed to continue the construction of the dam across Red River and to carry this work as far as possible without interrupting navigation.

"It is also proposed to begin the cut across Carr Point as soon as practicable, and to do this work by dredges working at both ends and a land force working along the whole length of the cut.

"It is expected that the dam will be completed during the coming season of high water, and it is proposed to deepen the best channel in the Upper Old River, through Sugar-House Chute, by dredging so that it will become the outlet of Red River and a navigable channel during the coming low-water season.

"In case the cut is not opened by the time of the next low-water season, and it is not probable that it will be, it is proposed to establish and maintain navigable communication between the Mississippi and Red Rivers till the cut is completed by such dredging as may be necessary between the upper end of the cut and the Mississippi River.

"After the completion of the cut the Upper Old River will be obstructed below the upper end of cut.

"The caving banks have caused some injury to the shore protection of the completed dams in the Atchafalaya River, which should be repaired.

"After the completion of the above, it is proposed to construct Sill and Dam No. 6 in the Atchafalaya River with the funds that may be available."

At its meeting of November 27, 1890, the Commission approved the above project with modifications, as follows:

That a navigable channel be secured north of Turnbull Island before the Red River Dam is raised above the second tier of cribs.

That the second tier be covered with a layer of stone.

That the portion of the third tier of cribs already built be used at the two ends of the dam.

That the dredging of Upper Old River be undertaken as soon as practicable and carried to completion before any dredging work is commenced on the canal through Carr Point.

That the approval of the project for Atchafalaya Sill and Dam No. 6 be postponed until a subsequent meeting of the Commission.

In pursuance of the above, work on the Red River Dam which had already been begun was continued and preparations made for undertaking dredging in Upper Old River. Needed alterations and repairs were made to the dredge *Pah-Ute*, and a larger dredge of the same character (Menge patent), called the *Menge*, was borrowed from the plant of the third district. This dredge also required extensive repairs and alterations.

Dredging was begun on December 4, 1890, and continued with several interruptions until February 2, 1891, when operations were suspended for the season on account of high water. The work done was mostly in the shallowest part of Upper Old River, just beyond the point where it divides into the three chutes, and near the lower end of Turnbull Island. This work was prosecuted under rather discouraging conditions and very little was accomplished. The material in the bed of Upper Old River is a very soft mud, as was found by examinations made throughout its whole length, and when brought up by the dredge much of it was in a semiliquid condition. The buckets of the dredge not being water-tight much of the material ran out of them as they came above the water, and the dump scows had to be altered to hold it. When discharged on the side of the dredge it ran back into the excavation, and there was ultimately very little greater depth where the dredges worked than before. The natural forces at work to close this channel are believed to be far more effective than any efforts it has been practicable to make to produce the opposite result.

At the meeting of March 20, 1891, the commission directed that the Red River Dam be raised to a height of 5 feet above low water, or to such less height as might be deemed necessary by the officer in charge to create a current through Sugar-House Chute sufficient to remove solid matter in suspension; that with the aid of such current the excavation of Sugar-House Chute be undertaken by stirring, scraping, lifting in buckets, lifting by pumps, or otherwise, as might be found most expedient; that all excavation at Carr Point be for the present deferred; and that brush be substituted for clay and gravel in the Red River Dam.

Dredging was resumed accordingly as soon as the water fell sufficiently, and is now in progress, the material being towed away and dumped, so far as the number and capacity of the dump scows available will permit, and the remainder of the material dredged being run off at one side through a long chute.

The rapid fall of the Mississippi and unusual floods in the Upper Red River resulted in a very strong current through Old River, which has now continued for several days, and the Mississippi has a decidedly red color at New Orleans. It is hoped that these conditions may assist in producing more noticeable effects from the dredging.

For use in keeping Lower Old River open during low water, where the material to be moved is more stable, it is believed that the dredging plant now on hand, as recently altered and improved, will prove very efficient.

When work on the Red River Dam was stopped by high water, the first and second tiers of cribs had been sunk for a length of 210 feet from the eastern end of the dam. The cribs for completing this tier were moored to the bank, and so remained during high water. Preparations for sinking them are now in progress. The completion of this course will bring the top of the dam up to a general grade of 1 to 3 feet below low water, provided no further settling occurs. The greatest settling noticed after sinking of cribs was finished last season was about 7 feet at one point, but this is probably attributable in part to compression of the structure itself, and not wholly or perhaps not at all to subsidence of the river bottom, since a large amount of rock was deposited on the dam after the last cribs were sunk.

The line of the proposed Carr Point Canal was surveyed and negotiations entered into with the owner for purchase of the necessary land. Approval of the purchase of 142.5 acres for the sum of $500, was received from the Chief of Engineers, but no further action was taken, since the opening of this canal will depend upon progress made with other parts of the work. With the consent of the owner experiments were made with the dredges at the western end of the proposed canal to determine whether they could be used to advantage in opening the canal. Considerable difficulty was encountered from the stumps of trees which ran down to a depth of 20 feet, but in the main the experiments were satisfactory.

Caving of the banks has continued to some extent in the vicinity of the Atchafalaya sill dams, and certain repairs have been made to the shore protection at both sills.

During the high water several leaks appeared in the levee built by the United States in connection with these works of improvement at Simmsport and they were stopped by throwing in earth on the river slope of the embankment.

In addition to the local survey of Carr Point Canal, a topographical survey was previously made of the entire point and of a portion of Turnbull Island opposite. Resurveys were made of the Atchafalaya Reach in the vicinity of the sill dams and of a portion of Turnbull Island at the end of Red River Dam. Drift soundings were recently taken in Red River above and below the dam and in the Atchafalaya.

Serious inconvenience has been experienced in the conduct of this work, owing to its being situated in an isolated locality with the nearest telegraph and railroad station 30 miles distant. Labor is very difficult to procure at any price during the summer, and at any season the expense of conducting the work is necessarily greater than would be the case were the surroundings more inviting. This being the only available place under control of the Government in that part of the district for the storage of tools and materials used during floods for work on the levees, the inconvenience of the lack of facilities for communication was most emphatically demonstrated during the last high water, and recommendation was accordingly made and approved for the construction of a telephone line to connect the works with West Melville, the nearest station on the Texas and Pacific Railroad. This line is now being erected, and in addition to its usefulness during high water it will greatly facilitate the direction of the regular work.

ROCK QUARRY.

The rock for the Red and Atchafalaya improvements, as well as for the improvement at Plaquemine, La., which is in charge of this office, but not under direction of the Mississippi River Commission, has been obtained from quarries near Harrisonburg, La., on the Ouachita River, about 80 miles from Turnbull Island.

A quarter boat with men and tools were sent up and work begun on November 5, 1890, at Harrisonburg. By February 15, 1891, all the rock that could be advantageously procured here had been taken out and the force was moved to a new quarry which had not been previously worked on Rawson Creek, a tributary of the Ouachita, which comes in about 5 miles above Harrisonburg. Here a very thick ledge of excellent rock was found, and the force continued working it until May 23, 1891, when it was necessary to move out on account of falling river. This quarry seems to be capable of supplying a large amount of rock, but its location is objectionable since it is 3 miles up the creek, which is very narrow and crooked and only navigable in high water.

A transfer was then made to quarries previously worked on Gaster Creek, where a considerable amount of rock that had been quarried the season before was removed and more quarried out. When the stage of the river compelled the abandonment of this place a new quarry was opened on Bœuf River, about a mile above its junction with the Ouachita. This quarry promises a considerable supply and the place can be reached more easily and at a lower stage of the river than the Rawson Creek quarry.

In order to facilitate operations a steam drill was ordered toward the latter part of the season, but the river fell so rapidly that by the time the drill arrived it was not expedient to put it in operation this season.

In all 16,306 tons of rock have been taken out this season, of which 5,192.1 tons have been delivered at Plaquemine, 3,952 tons used on the Red River Dam, and 7,162 tons placed on the bank at Turnbull Island, making 11,114 tons delivered for the Red and Atchafalaya works.

Of course the expense of the quarry is borne proportionally by the Red and Atchafalaya and the Plaquemine appropriations. The average cost of rock delivered at Turnbull Island was $1.918 per ton.

The approximate value of material for construction on hand at Turnbull Island is $49,175.33.

The work recommended for the ensuing year is the opening of the Carr Point Canal, obstructing Lower Old River, and completion of Red River Dam, and it is estimated that $350,000 can be profitably expended.

This work has been under the immediate charge of Assistant Engineer W. G. Price, assisted since December 5, 1890, by Assistant Engineer G. Ed. Mott.

IMPROVING MISSISSIPPI RIVER (NO LIMIT)—RECTIFICATION OF RED AND ATCHAFALAYA RIVERS.

Money statement.

July 1, 1890, balance unexpended	$23,731.63
Amount appropriated by act approved September 19, 1890	225,000.00
	248,731.63
June 30, 1891, amount expended during fiscal year	101,622.35
July 1, 1891, balance unexpended	147,109.28
Amount that can be profitably expended in fiscal year ending June 30, 1893	350,000.00

Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.

NEW ORLEANS HARBOR.

The city of New Orleans, with its various suburbs, lies on both banks of the Mississippi River at a distance inland of 104 miles from the South Pass. This pass is the only one of the numerous mouths of the river having sufficient depth of water to admit seagoing vessels of deep draft, and it therefore is the entrance from seaward to the Mississippi River and the harbor of New Orleans. The city is the metropolis of the South, and besides being the most important seaport on the Gulf of Mexico, ranking seventh among the ports of the United States in the value of its imports, while in the value of exports it is only exceeded by New York City; it also ranks first among the towns on the Mississippi in the commercial importance of its river traffic.

New Orleans Harbor as at present developed consists solely of a length of about 13 miles of the Mississippi River, which here has an average width of about 2,200 feet, and it comprises four comparatively straight reaches of various lengths and four curves or bends, two of these bends, the one at Algiers Point and the one at Carrollton being quite abrupt. The depth of the river is in general ample for the purposes of navigation.

The entire country in the vicinity is of alluvial formation and is consequently low and flat, being highest along the river bank and having a gentle slope back toward the swamps. During floods the river reaches a height of 5 or 6 feet above the highest ground in the city, and the levees, which are essential for the prevention of overflow, are as a rule necessarily built close to the river bank in order to meet the requirements of the various interests along the water front.

As in other river harbors the construction of regular docks or slips and piers is as a rule impracticable, owing to the variation in height of the water, the unstable nature of the banks, the swift current, and the deposition of silt. The water front is occupied principally by continuous wharves, to which vessels must moor alongside; and since there are no good anchorage grounds, owing to the current and the great depth of water, the conditions generally in the harbor are such as to require an unusual development of water front to accommodate a given amount of shipping.

Although the condition of the river and of its banks below Baton Rouge is one of comparative stability, when contrasted with the extraordinary changes which often occur above, the damage that results from even slight changes of the river in a port like New Orleans becomes serious. In general the action of the river is to undermine, cut away, and cause caving or sliding down of the banks on the concave shore at the bends and for some distance below them, resulting in the destruction of wharves, levees, streets, and sometimes of sheds and buildings. Where this action occurs on one bank a deposit of sediment and consequent shoaling and damage to the water front on the opposite shore usually takes place also. In certain localities in the straight reaches similar destructive effects have been produced by the caving of the banks, due to the weight of masses of sediment deposited during high water, which, when deprived by the falling river of the support which the water afforded during flood time, causes large portions of the bank to crack off and slide down. This action usually takes place only during falling water, but the destructive effects in the bends goes on to a greater or less extent at all stages of the water, and in addition to the immediate damage on the water front there is the danger of much more serious disaster resulting from the breaking of the levee during high water, and flooding the city.

The object of the works of improvement in New Orleans Harbor is to check and if possible prevent the detrimental action of the river, as above described, and to maintain the river bed and banks in a condition of permanency.

Under the approved project the work now in progress to accomplish the above objects consists in the construction of submerged inclined spur dikes along the caving banks, which extend out normally to the bank line at intervals of from 500 to 1,600 feet.

Each spur dike rests on a wide mattress made of willows, brush, and timber, which is sunk in place by being loaded with stone, and which is intended to prevent any scouring action on the river bottom by eddies or local currents which may be produced by the dike. On this mattress the dike is built up by sinking successive layers of mattresses or cribs of diminishing widths, the construction of which is similar to that of the first mattress except that they are made thicker. The work is so planned that the top of the completed dike at the shore end will be below low water line, and the crest of the dike has an approximately regular slope of about 3 horizontal to 1 vertical, its outer end resting on the river bottom in deep water. In the vicinity of wharves and docks the crest of the dike is placed low enough so it will not interfere with vessels, but in other localities the crest has been continued up to and united with the crest of the levee or the bank by an earth embankment paved with stone.

These structures are designed to check the velocity of the current along the shore and thus diminish the erosion and caving of the bank and cause deposit of sediment and the restoration of the bank line.

In certain localities their direct effect in bracing up the bank and so preventing the caving which is liable to take place during the falling of the river is also believed to be beneficial.

When this form of structure is used where the existing slope of the submerged portion of the river bank is not steep the foot mattress probably becomes the most important part of the spur and the dikes act more as an interrupted bank revetment.

The following work of improvement in general accordance with the project as above outlined had been done prior to July 1, 1890:

A continuous mattress about 400 feet in length had been placed just above the caving bank in Carrollton Bend, but this form of protection was afterwards abandoned.

Six spur dikes had been built in the Gouldsboro Bend, two in the Greenville Bend, and four in the third district reach; and surveys, plans, and estimates for continuing the work had been made.

At the beginning of the year the balance available was $48,515.36, and there was on hand material for construction valued at $11,399.

The upper works of the tug *Tilda*, which had been burned, were first rebuilt, damage to her machinery repaired, and tools and fittings which had been destroyed were replaced. As soon as these repairs were completed, the fleet of barges was towed to the vicinity of Bayou Sara, Louisiana, to cut willows for the season's work. Labor was very scarce and difficult to obtain at that season, and the barges did not return till September 19. In the mean time repairs to the remainder of the plant were made and new crib and mattress ways were built. Upon arrival of the willows the construction of mattresses and cribs was commenced.

On October 15, 1890, the allotment of $90,000 for this work, from the appropriation of September 19, 1890, was approved, and in obedience to the instructions of the president of the Commission the following project was submitted for carrying on the work:

It is proposed to complete the six spur jetties now in process of construction in the Carrollton Bend at Southport, and to put in six spur jetties, or such less number as the funds available will allow, on the left bank of the river in the third district of the city of New Orleans, these jetties to be located approximately as shown on the accompanying map, and to be similar in design to those already built opposite the Ursuline convent.

"Spur No. 4, in the Carrollton Bend, is completed, and the mattress for Spur No. 3 nearly ready to sink. Upon completion of Spur No. 3, should there be no further caving just below Spur No. 4, where caving has recently taken place, it is proposed to construct first Spur No. 1 and then Spur No. 5 in the third district. Should the caving continue below Spur No. 4 in the Carrollton Bend, Spur No. 5 should be completed before the force is transferred to the third district, and in any case it is proposed to carry the two works along so as to best arrest and prevent caving of the river bank.

"It is also proposed to make such surveys in the harbor as may be necessary to ascertain the effect and present condition of works already completed, and to provide for the care and repair of the plant when not in use till the beginning of the next working season."

This project having been approved December 16, 1890, work was continued accordingly.

An additional allotment of $10,000 for the work was made November 26, 1890.

The construction of the mattress for Spur Dike No. 4 was commenced September 24. It was sunk November 7, and the dike completed November 13.

The mattress for Spur Dike No. 3 was commenced October 6; it was sunk November 21, and the dike completed December 22.

As there were still indications of continued caving below Dike No. 4, Dike No. 5 was next built in pursuance of the project. The mattress was commenced December 22 and sunk January 13, 1891. The dike was completed January 22. The height of the river prevented further construction work for this season, and the fleet was taken to laying-up quarters and needed repairs to plant at once begun.

During the latter part of the construction operations the supply of willows was exhausted and it became necessary to procure an additional supply in open market, which caused considerable delay and additional expense.

The principal dimensions and field cost of the dikes constructed were as follows:

No.	Dimensions of foot mattresses.	Greatest height.	Cost.
	Feet.	*Feet.*	
3	415 by 140	45	$17,632.05
4	355 by 130	50	13,008.69
5	400 by 120	40	10,901.79

Near the close of the work the tug *Tilda* lost her wheel and the outboard end of her shaft. Her crank had previously been broken and temporarily repaired, and so she was put in dock and a new wheel, shaft and crank complete fitted. In making these repairs it was found that her timbers and planking were in such a rotten condition that it was necessary to largely rebuild her hull. She was also furnished with a powerful steam pump for pumping out the barges and as a protection to the fleet against fire.

Repairs were also made to the barges and a house built on one of them to serve as a warehouse. The old warehouse barge, being rotten beyond economical repair, was beached, and it will be used for the storage of worthless material until disposed of.

Extensive repairs to the hull of the quarter boat were also necessary and are now in progress. The steam launch No. 1 was condemned, her machinery being worn out and her hull so badly rusted as to be useless. Steam launch No. 5 was transferred to this district from the secretary of the Commission and arrived May 16. She has already proved a very useful boat for this work.

A survey was made by Assistant Engineer Hardee in August, 1890 of a portion of the river in the third district reach, on the left bank, just above the spur dikes built in 1889, adjacent to the Ursuline convent, upon which the project for works of improvement in that locality was based. Mr. Hardee also made a survey in October of the completed work in the Gouldsboro Bend, right bank, to determine the condition and effect of the six spur dikes which were completed in 1888, and the bank line in this vicinity has recently been surveyed again.

The contours have been platted in connection with those determined by surveys made before the work was begun. They show that the dikes are apparently intact, and that there has been no damage to the levee or water front of any consequence, though there has been some slight caving of the bank. In deep water beyond the foot of the spurs the 100-foot contour seems to have been moved out towards the center of the river, but between the spurs there has been a noticeable cutting or scour. The bend in the river here is very gentle.

Assuming that the immediate object of the work was to arrest the progress of caving and to save the levee and property or shore from destruction, or at least to greatly prolong their existence, the work has undoubtedly been a success, and there has been a material diminution of the current along shore; but the secondary result which was hoped for; that is, a deposit between the dikes and a building out of the bank line, has evidently not taken place, nor is it likely to. The apparent moving out of the 100-foot contour is not regarded as a direct and beneficial result positively attributable to the dikes alone.

On the night of March 16 the levee between the two spur dikes in the Greenville bend broke, and the crevasse gradually enlarged so that the downstream side of the opening finally extended beyond the lower spur about 600 feet and the upstream end reached the upper one. This crevasse has doubtless largely undone the beneficial results produced by the dikes, but a survey to determine the extent of the injury has not yet been made.

The four spur dikes in the third district, built in 1883, are in apparently good condition and have accomplished the object for which they were built, there having been no caving in their immediate vicinity since their completion. These dikes dif-

fer from other similar works in the harbor in being connected with the main levee by spur levees built of earth and paved with stone, running out over the "batture" and down to the head of the dike proper. This portion of the dike was designed to induce deposit on the batture and restore bank lost by caving.

In the Carrollton Bend local caving in the vicinity of the spur dikes built last fall was not entirely arrested, and a portion of the wharf and shed of the Louisville, New Orleans and Texas Railroad Company, which was situated immediately on the bank at the head of the Spur Dike No. 4 has been destroyed, and it has been necessary to move a portion of the railroad track leading to the wharf.

This confirms the prediction of my predecessor in this office, who in his last annual report expressed grave doubts of the work being completed in time to save this property, and it is probable that if the work is completed in accordance with the present project there will be considerable caving between the dikes before the river and bank assume a condition of stability, and that a sacrifice of a certain amount of bank will be unavoidable.

As soon as the stage of water will permit and the willows which are now being cut arrive construction work will be resumed, beginning on Spur Dike No. 1, in the third district reach.

A house has been leased in the vicinity and fitted up for quartering and subsisting workmen, as the repairs to the quarter boat will not be completed for several weeks. A considerable amount of rock ballast, brought in vessels to the harbor, has been purchased, and there is now nearly enough on hand for the season's work.

The construction of two additional barges at an estimated cost of $3,500 is recommended.

The tug *Tilda* has cost for repairs and improvement during the year $4,750.37. Her estimated value before her house was burned off was $5,000. At this date she is again disabled and laid up with a broken wheel.

The following vessels not belonging to the regular fleet of the district were required for the work during the past year and they rendered service as stated:

	Days.
Snag boat *Florence*, borrowed from Captain Willard, for work during high water	61
Tug *Parker*, borrowed from Captain Townsend, for work during high water....	37
Tug *Laurel*, chartered for discharge observation party at Warrenton and Natchez	40
Tug *Alert*, chartered to take place of *Tilda* in New Orleans Harbor work while latter was disabled	86
Tug *Corsair*, chartered to take place of *Tilda* in New Orleans Harbor work while latter was disabled	2

It is obvious that the district is deficient in towboats.

The steamer *Newton* is economically employed during only a portion of the year, and for the remainder of the time the service which she renders could be performed by a smaller boat at less expense.

The tug *Tilda* is too small for the work of the harbor, as the necessary frequent repairs indicate, and though she is in excellent repair now, her wooden hull has a limited life.

It is therefore recommended that an iron-hull tug be procured for the work of the harbor, which will also be available for towing barges about the district for protection work during high water, towing willows and rock, and for any other service required. There is ample depth of water to allow such a boat to go anywhere in the district, and it is believed she would render more efficient and economical service for a good portion of the time than is now rendered by the *Newton;* and when the *Newton* gets beyond economical repair it may not be necessary to replace her. Such a boat could probably be obtained for $26,500; making the estimate for new plant—

Two barges, at $1,750	$3,500
Iron hull tug	26,500
Total	30,000

The work recommended to be done in continuation of the general project is bank protection to arrest caving between Carrollton Bend and Exposition Wharf on the left bank, where the caving has already reached the levee in two places, and in the vicinity of Soraparu street on the same bank opposite Gretna, where the street and car track have been entirely cut off at one point and seriously threatened at another by caving.

It is estimated that the sum of $200,000 could be profitably expended during the year ending June 30, 1893.

The work of improvement in New Orleans Harbor was in local charge of Assistant Engineer Douglas until November 7, 1890, when he was relieved from that duty to take charge of levee work which was at that time being undertaken on an extended scale. Since that date Assistant Engineer Garvin has had charge of the harbor work.

IMPROVING MISSISSIPPI RIVER (NO LIMIT)—NEW ORLEANS HARBOR, LOUISIANA.

Money statement.

July 1, 1890, balance unexpended	$48,519.62
Expenses Office Chief of Engineers	112.00
Balance unexpended	48,407.62
Amount appropriated by act approved September 19, 1890	100,000.00
	148,407.62
June 30, 1891, amount expended during fiscal year	78,688.08
July 1, 1891, balance unexpended	69,719.54
Amount that can be profitably expended in fiscal year ending June 30, 1893	200,000.00

Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.

LEVEES.

At the time of the last Annual Report no levee work was in progress under direction of this office.

The following-named levees had been built, in whole or in part, enlarged, or extensively repaired by the United States previous to that date, and were generally known as United States levees:

Name of levee.	Below Cairo.	Right or left bank.	Approximate length.
Above Red River.	*Miles.*		*Miles.*
Point Pleasant	624	Right	5.0
Hard-Times-Wilson	631	...do	10.2
Hard Times	633	...do	0.8
Evergreen	636	...do	2.0
Hardscrabble and Bondurant	640	...do	5.2
Kempe	659	...do	3.9
Lake Concordia	693	...do	18.5
Greens to Fairview	722	...do	11.0
Total			56.6
Below Red River.			
Atchafalaya River to Red River Landing	762	Right	6.0
Red River Landing downstream	766	...do	1.0
Hog Point to Raccourci	767½	...do	3.2
Raccourci crevasses	784	...do	1.1
Morganza	789	...do	1.3
Stewarts	791½	...do	0.3
Point Coupee	797	...do	1.1
Bonnet Carré	927	Left	2.4
Total			16.4
Total in district			73.0

The above does not include levees built by the United States and afterwards abandoned or thrown out of the main line by the construction of new lines behind them, as was rendered necessary by crevasses or changes in the river bank, but only comprises the approximate length of embankment that could then be considered as effective levee or capable of being made so by restoring breaks.

It will be observed that by far the greater portion of these levees were on the Tensas Basin or above the mouth of Red River on the right or western bank. Previous to the present year no extensive levee building had been done by the United States in any other part of the district.

The unprecedented flood of 1890 was a severe test of the levee system in this district, and when the last Annual Report was submitted there were twelve crevasses, some of them of extraordinary size, that still remained to be closed. In addition to actual openings the prolonged high water had caused or developed many weak places in the levees, and showed that they could not again be subjected to such a strain without the greatest care and vigilance to prevent disaster. Moreover, when the flood subsided, the rapidly caving banks in many places weakened or seriously threatened the levees at points which had safely withstood the recent high water, but which of course had to be rebuilt before another flood. The work of repair

and rebuilding was undertaken by the State authorities of Louisiana as soon as possible after the water went down, and was energetically prosecuted, but at the time the appropriation of September 19, 1890, became available there remained a large amount of work unprovided for which it was absolutely necessary to finish before another high water to prevent the occurrence of even greater disasters than those of 1890.

The following allotments were made from the amount appropriated by the river and harbor act of September 19, 1890, for levees in this district:

Tensas Basin	$210,000
Right bank, below Red River	130,500
Left bank, below Red River	94,500
Total	435,000

Five per cent. of each of the above amounts was by direction of the Commission to be retained for the care and maintenance of the levees and the remainder was to be available for new work.

Upon recommendation of the Board of Officers on Building and Repairing Levees of October 23, 1890, the construction of the following levees was authorized under the above allotment:

Tensas Basin.—Bedford, Ferriday, Buckridge, Arnauldia, Kempe, Henderson, Gibson Landing, Deer Park.

Right bank, below Red River.—Nina, Highland, Barroza, Evergreen.

In response to advertisements bids for the above were received as follows:

Abstract of proposals received in response to advertisement dated November 9, 1890, for construction of levee in the fourth district, Mississippi River, opened November 20, 1890.

TENSAS BASIN.

[Price per cubic yard.]

No.	Name and address of bidder.	Bedford (30,500 cubic yards).	Kempe (40,000 cubic yards).	Ferriday (75,000 cubic yards).	Arnauldia (20,000 cubic yards).	Henderson (55,000 cubic yards).	Deer Park (75,000 cubic yards).
		Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1	Ernest Hyner, Greenville, Miss	*20.3					18.3
2	S. L. James, jr., New Orleans, La	$20\frac{1}{2}$	*23				
3	Kilpatrick & Storer, Memphis, Tenn			*21	*17		
4	Manning & Howe, Lake Providence, La	$21\frac{1}{2}$				*23	$19\frac{7}{8}$
5	Flynn & De Garis, Memphis, Tenn						*$17\frac{3}{4}$
6	Andrews & Ogden, Baton Rouge, La						$22\frac{3}{4}$
7	W. L. Killebrew, Greenville, Miss	23	27	31	20	35	34
8	Luke Madden, Delta, La.†	$23\frac{3}{4}$					
9	T. C. Bedford, Vicksburg, Miss.†	26					
10	William Curry, St. Joseph, La		$29\frac{3}{4}$				
11	A. P. Martin, Natchez, Miss.†		31		27		

RIGHT BANK BELOW RED RIVER.

[Price per cubic yard.]

No.	Name and address of bidder.	Nina (75,000 cubic yards).	Highland (330,000 cubic yards).	Barroza (200,000 cubic yards).	Evergreen (70,000 cubic yards)
		Cents.	*Cents.*	*Cents.*	*Cents.*
1	Ernest Hyner, Greenville, Miss	19.7			
2	S. L. James, jr., New Orleans, La	*18			19.99
3	Kilpatrick & Storer, Memphis, Tenn				
4	Manning & Howe, Lake Providence, La				
5	Flynn & De Garis, Memphis, Tenn	$18\frac{3}{4}$	$24\frac{3}{4}$	$43\frac{3}{4}$	*19
6	Andrews & Ogden, Baton Rouge, La	18.45	*23.74	*26.99	20
7	W. L. Killebrew, Greenville, Miss	34	35	38	33
8	Luke Madden, Delta, La.†				
9	T. C. Bedford, Vicksburg, Miss.†				
10	William Curry, St. Joseph, La				
11	A. P. Martin, Natchez, Miss.†				

† Informal.

Total, 970,500 cubic yards.

Bids marked (*), the lowest received, were accepted and contracts were entered into.

Abstract of proposals received in response to advertisement dated November 14, 1890, for construction of Gibson Landing Levee, Tensas Basin, opened November 25, 1890.

No.	Name and address of bidder.	Price per cubic yard (about 330,000 cubic yards).	Total.
		Cents.	
1	W. L. Killebrew, Greenville, Miss	19⅜	$63, 937. 50
2	Ernest Hyner, Greenville, Miss	21	69, 300. 00
3	Castleman & Wilson, New Orleans, La	24	79, 200. 00
4	John Scott & Son, Vicksburg, Miss	29½	97, 350. 00
5	Augustus P. Martin, Waterproof, La	31	102, 300. 00
6	Laing, Smoot & Co., Dallas, Tex	31. 95	105, 435. 00
7	P. J. Coffman, Baton Rouge, La	35	115, 500. 00

Total amount available for this work exclusive of outstanding liabilities, $124,000. Contract was entered into with W. L. Killebrew for construction of this levee.

Abstract of proposals received in response to advertisement dated December 14, 1890, for construction of Buckridge Levee, Louisiana (Point Pleasant), opened December 23, 1890.

No.	Name and address of bidder.	Price per cubic yard (about 100,000 cubic yards).	Total.
		Cents.	
1	Manning & Howe, Lake Providence, La	18	$18, 000. 00
2	A. P. Martin, Waterproof, La.*	18¼	18, 250. 00
3	Ernest Hyner, Greenville, Miss	18. 3	18, 300. 00
4	Samuel L. James, jr., New Orleans, La	18. 75	18, 750. 00
5	Thomas W. Kilpatrick, Vidalia, La	19¾	19, 750. 00
6	Daniel Carey, Union P. O., La	25. 20	25, 200. 00

* Informal.

Total amount available for this work, exclusive of outstanding liabilities, $60,000. Contract was entered into with Manning & Howe for construction of this levee.

Owing to the late date at which the allotments became available it was necessary to use the utmost possible haste in determining the various lines. Through the kindness of Maj. H. B. Richardson, chief State engineer of Louisiana, all maps, surveys, estimates, and other information in his possession were placed at the disposal of this office, and with this aid the work of final location and staking out the lines was ably performed and with remarkable dispatch by Assistant Engineer Douglas, assisted by Assistant Engineer Hardee, and the delay in beginning work was less than the circumstances seemed at first to render unavoidable.

The early rise of the river and continued rains seriously interfered later in the season, but the only opening in the line which existed during high water that was due to failure to complete work undertaken by this office was at Henderson (713 R). This point is well down near the foot of Tensas Basin, and there are sloughs in rear leading directly across to Red River, so that the damage from the gap was entirely local and comparatively insignificant. The backwater did not even interfere with work on Deer Park levee, only a mile and a half distant below.

At Kempe (659 R) the old front line was intact when the new work was commenced, but it was breached by caving of the bank before high water, and a temporary protection levee had to be built to enable the back line to be finished.

At Ferriday Crevasse (693 R), in Lake Concordia levee, a protection levee was also necessary; and at Deer Park (722.5 R) 2 lines of protection levee were built.

Several new levees were in process of construction on the left bank below Red River at the time the allotment became available under a State organization known as the Pontchartrain levee board. Owing to legal complications, concerning the raising of funds by taxation, this board became embarrassed for money and were unable to complete the levees they had undertaken.

By authority of the honorable Secretary of War, upon the recommendation of the president of the Commission, this office assumed charge of those levees on November 20, 1890, and undertook to complete them by informal agreements with the contractors at the same price and upon the same general terms as were provided for in their contracts with Pontchartrain levee board. The following table shows in con-

densed form the history and status of all the new levees in charge of this office at the date of this report:

United States levee work in fourth district, Mississippi River, undertaken during the year ending June 30, 1891.

Name of levee.	Below Cairo.	Length.	Width of crown.	Slope on land side.	Slope on river side.	Greatest height.	Least height.	Average height.
Tensas Front (right bank):	*Miles.*	*Feet.*	*Feet.*			*Feet.*	*Feet.*	*Feet.*
Bedford	606	3,030	8	3 to 1	3 to 1	17.6	6.2	9.4
Buckridge*	624							
Kempe	659	2,405	8	3 to 1	3 to 1	16	9.1	10.6
Gibson Landing	683.5	13,888	8 to 10	3 to 1	3 to 1	25.6	8	11.7
Ferriday	693	3,355	8	3 to 1	3 to 1	26.2	7.4	12.0
Arnauldia	702	578	6	3 to 1	3 to 1	6.7	5.2	6.2
Henderson	712	1,705	8	3 to 1	3 to 1	16.2	12.4	13.4
Deer Park	722	10,285	8	3 to 1	3 to 1	13.4	5.3	7.8
Right bank, below Red River:								
Nina	806.5	6,159	6	3 to 1	3 to 1	31.6	1.7	9
Highland	815.5	5,170	8	3 to 1	3 to 1	21.2	2.8	14
Barroza	823	4,145	8	4 to 1	3 to 1	19.2	3.0	17½
Evergreen	857	3,400	8	3 to 1	3 to 1	16.0	1.6	14½
Left bank, below Red River:								
Shannon	837	4,813	8	3 to 1	3 to 1	12.1	3.1	11.5
Martinez	842	1,420	6	3 to 1	3 to 1	8.5	1.9	8.2
Gay to Hollywood	845	4,423	8	3 to 1	3 to 1	11.0	0.9	10.4
Woodstock	847.5	3,135	8	3 to 1	3 to 1	10.5	1.7	10
Hermitage	850	4,540	8	3 to 1	3 to 1	11.1	2.4	9.2
Grenada to Mount Olive	856.5	7,400	8	3 to 1	3 to 1	8.7	0.7	3.8
Southwood	875.5	4,855	8	3 to 1	3 to 1	11.1	0.9	10.8
Ashland to Linwood	878	4,032	6	3 to 1	2 to 1	4.0	1.0	3.3
Discharry	882	4,700	8	3 to 1	3 to 1	14.3	0.6	13.4
Irvine	892.5	1,325	6	3 to 1	3 to 1	8.6	1.6	7.4
Union	893.5	1,080	6	3 to 1	3 to 1	7.6	1.4	8.4
Lilly	900.5	2,269	6	3 to 1	3 to 1	10.6	1.9	9.5
College Point to St. Michael	903.5	1,637	6	3 to 1	3 to 1	5.0 and 9.2	0.6 and 0.6	3.0 and 8.8
Terre Haute to Hope	919.5	10,640	5 and 6	3 to 1	2 to 1	4.0 and 8.2	1.2 and 1.2	3.0 and 6.7
Cornland	922	1,336	6	3 to 1	3 to 1	10.3	0.9	10.0
Destrahan	939	1,272	5	2 to 1	2 to 1	5.1	1.6	3.0
Frellsen to Almedia	942.5	7,350	5	3 to 1	2 to 1	4.3	1.3	3.8

Name of levee.	Grade of crown above high water of 1890.	Total (net).	Net paid for by the United States.	Amount paid by United States.	When commenced.	When completed.
Tensas front (right bank):	*Feet.*	*Cubic yards.*	*Cubic yards.*			
Bedford	1.8	43,738.18	43,738.18	$8,860.85	Dec. 18, 1890	Mar. 7, 1891
Buckridge*						
Kempe	3.0	38,490.70	38,489.71	9,744.53	Dec. 10, 1890	Mar. 8, 1891
Gibson Landing	3.0	289,637.24	129,721.48	22,637.62	Dec. 4, 1890	(†)
Ferriday	3.0	70,274.33	72,472.03	15,144.13	Dec. 1, 1890	Mar. 25, 1891
Arnauldia	1.5	3,289.11	3,289.11	559.15	Dec. 25, 1890	Feb. 27, 1891
Henderson	3.0	42,372.23			Dec. 3, 1890	(‡)
Deer Park	2.4	99,458.54	99,623.85	17,624.12	Dec. 10, 1890	Mar. 20, 1891
Right bank, below Red River:						
Nina	3.0	95,999.91	88,037.41	14,262.05	Dec. 18, 1890	§June 14, 1891
Highland	3.0	127,895.96	127,895.96	30,551.07	Dec. 17, 1890	May 31, 1891
Barroza	3.0	164,860.69	164,860.69	46,713.05	Dec. 16, 1890	May 30, 1891
Evergreen	3.0	93,654.73	30,488.71	5,213.56	Jan. 1, 1891	(‖)
Left bank, below Red River:						
Shannon	3.0	91,037	77,136	14,077.32	(¶)	Mar. 28, 1891
Martinez	3.0	12,889	4,452	812.49	(¶)	Dec. 27, 1890
Gay to Hollywood	3.0	67,732	39,428	7,097.04	(¶)	Feb. 28, 1891
Woodstock	3.0	48,277	29,182	5,249.84	(¶)	Dec. 27, 1890

* Authority received to annul contract.
† Forty per cent. completed; to be finished January 1, 1892.
‡ To be finished September 1, 1891.
§ Six hundred feet left open, to be completed February 1, 1892.
‖ About 86 per cent. completed; to be finished July 31, 1891.
¶ There is no record in this office to show when these levees were commenced. They were transferred to the United States Government on November 20, 1890.

United States levee work in fourth district, Mississippi River, etc.—Continued.

Name of levee.	Grade of crown above high water of 1890.	Total (net).	Net paid for by the United States.	Amount paid by United States.	When commenced.	When completed.
Left bank, below Red River—Continued.	*Feet.*	*Cubic yards.*	*Cubic yards.*			
Hermitage	3.0	56,466	24,218	$4,056.51	(*)	Dec. 27, 1890
Grenada to Mount Olive.	3.0	24,944	17,602	3,168.36	(*)	Feb. 24, 1891
Southwood	3.0	75,843	62,942	11,612.80	(*)	Mar. 23, 1891
Ashland to Linwood	3.0	14,828	11,230	2,246.00	(*)	Jan. 31, 1891
Discharry	3.0	109,659	75,145	14,935.07	(*)	Mar. 16, 1891
Irvine	3.0	9,759	9,759	1,756.62	(*)	Jan. 31, 1891
Union	3.0	10,507	10,507	1,891.26	(*)	Do.
Lilly	3.0	27,739	22,900	4,577.71	(*)	Jan. 17, 1891
College Point to St. Michael.	3.0	12,147	7,417	1,334.32	(*)	Jan. 5, 1891
Terre Haute to Hope.	3.0	33,344	15,899	2,860.92	(*)	Feb. 23, 1891
Cornland	3.0	17,762	14,486	2,748.00	(*)	Jan. 31, 1891
Destrahan	3.0	3,052.7	3,052.7	518.65	(*)	Jan. 9, 1891
Frellsen to Almedia.	3.0	24,258.3	6,521.3	1,109.97	(*)	Do.

* There is no record in this office to show when these levees were commenced. They were transferred to the United States Government on November 20, 1890.

Of the levees in this list remaining incomplete at this date, Buckridge was delayed by refusal of property owners to consent to the line selected. The State authorities have since undertaken to construct a levee on another and longer line, and authority has been received to annul the contract for the line fixed upon by this office.

The contract time for Gibson Landing (683.5) does not expire until January 1, 1892, and the prospects for the completion of the work by that time are favorable.

At Henderson (713 R) the work was interrupted by high water.

The time for the completion of Nina was extended till February 1, 1892, to enable the sugar mill and other buildings on the adjacent plantation to be moved after the present cane crop is worked up.

The time for the completion of Evergreen was extended till July 31, 1891, the old front line being still intact and the work having been greatly interfered with by bad weather and seepage water.

The consent of property owners to the line determined upon at Southport has not yet been obtained.

Surveys and estimates for new levees, which should be constructed during the ensuing year, have been made by this office, as follows:

Kempe (659 R), front line threatened by caving bank, 225,000 cubic yards, at 28 cents	$62,000
Hardscrabble (639 R), front line threatened by caving bank, 223,200 cubic yards	60,000
Highland (615.5 R), to complete line begun by United States; caving bank partly breached, front line, 230,000 cubic yards, at 20 cents	46,000
Terre Haute (919.5 L), to build new line further from river; front line very much exposed and badly wave-washed, 35,000 cubic yards, at 20 cents	7,000
Ferriday Crevasse (693 R), to close crevasse, 2,000 cubic yards, at 20 cents	400

The above are all United States levees. In compliance with my request Major Richardson, Chief State Engineer, has furnished the following approximate estimate of necessary levee work which, up to June 15, 1891, had not been provided for by the State authorities:

Name.	Cubic yards.	Amount at 20 cents per cubic yard.	Name.	Cubic yards.	Amount at 20 cents per cubic yard.
Cottage Home (649 R)	153,000	$30,600	Point Barrow (885 R)	16,000	$3,200
Stewart (791 R)	183,000	36,600	Minnie (896.5 R)	20,000	4,000
Red Store (795 R)	118,000	23,600	Home Place (905.5 R)	60,000	12,000
St. Francis (799 R)	5,000	1,000	Belmont (907 L)	13,000	2,600
Irvine (800 R)	2,000	400	Teissier (909 L)	24,000	4,800
Leban (834 R)	33,000	6,600	Poche (912 L)	12,500	2,500
Barroza extension (823 R)	75,000	15,000	Bonsecour (920 R)	18,500	3,700
Towles (851 L)	9,600	1,920	Prospect (937 L)	58,500	11,700
Billings (852.5 L)	31,500	6,300	Boisblanc (952 L)	21,000	4,200
Gourrier (853 R)	14,000	2,800	Ames (959 R)	100,000	20,000
St. Gabriel (862 L)	26,000	5,200			
Southwood, Waterloo (876 L)	88,500	17,700	Total	1,082,100	216,420

Making the entire sum which is needed for new levee work in this district during the year, $357,000.

It is therefore manifest that any sum which will probably be made available could be usefully applied to levee building in this district during the ensuing year, but I do not make a definite estimate of work of this character which, in my judgment, it is advisable or necessary to do, since such an estimate would necessarily be largely dependent upon questions of policy which it is beyond my province to consider.

PROTECTION, CARE, AND MAINTENANCE OF LEVEES.

As previously stated, the Commission directed that of the total allotment for levee construction 5 per cent., or a sum of $21,750, should be retained "for the care and maintenance of levees in the several localities for which the allotments are made," and notice was received on March 24, 1891, of the following additional allotments "for the protection of existing levees from threatened danger by high water."

Levees Tensas Basin, fourth district	$40,500
Levees, right bank below Red River, fourth district	43,750
Levees, left bank below Red River, fourth district	23,688

The river began to rise early in the season, and by the middle of February had reached such height as to cause apprehension of danger, particularly since a large amount of new work was unfinished, gaps remained open, and the several lines in general were in poor condition to withstand a flood. That part of the district above Red River gave the greatest anxiety, since between Vicksburg and Bayou Sara, a distance of 200 miles, the only telegraph stations on the river are at Natchez and St. Joseph. The country is thinly settled and there is no railroad within reach of the river except at Natchez. This part of the river also comprised most of the existing United States levees, the more important of the new levees, and nearly all the open gaps of any consequence. The tools and material previously used for protection work were stored at the depot of the Red and Atchafalaya works near Simmsport, which is 30 miles from a railroad station or telegraph office.

The steamer *General Newton* was sent to this part of the district, and was engaged during the continuance of high water in transporting tools and material to places where needed, and in patrolling the entire line.

The United States snag boat *Thos. B. Florence* was also engaged in similar duty, both above and below Red River. She belongs to the works in charge of Capt. J. H. Willard, Corps of Engineers, U. S. Army, and was rendered available for this service through the courtesy of that officer.

The tug *Parker*, belonging to the third district, Mississippi River, under charge of Capt. C. McD. Townsend, Corps of Engineers, U. S. Army, was also employed for a short time on protection work in this district; but she was soon needed in the third district again, and was accordingly returned.

The flood did not reach as great a height as during 1890, and no raising of the levees was necessary.

The following table shows the localities and nature of the protection work done:

Localities.	Nature of protection.
Point Pleasant (625 R.)	Protected with sacks to stop wave wash.
Hard times (632 R.)	Repairs to wash caused by current.
Kempe (659 R.)	Stopping "sand-boil." Protection of levee in front of new work. Revetting front slope of new levee with sacks. "Run-around" at point where caving bank threatened angle in front line. Drainage ditches and banquette in rear of new work.
Gibson Landing (683 R.)	Stopping craw-fish holes in old front line.
Ferriday (693 R.)	Stopping small crevasse.
Arnauldia (702 R.)	Sack revetment on front of new work.
Henderson (713 R.)	Protection levee in front of new work. It gave way, and work stopped.
Deer Park (722 R.)	Protection levee in front of new work.

Below the mouth of Red River the facilities for communication and transportation of material are in general very good, and the local interests and resources are much greater than above, so that comparatively little protection work in this part of this district was required on the part of this office. Between Baton Rouge and New Orleans a railroad runs near each bank of the river with frequent stations. The country is all settled and labor is abundant.

In the early part of the high-water season a barge was prepared for such protection work as might become necessary by building on it a temporary house to accom-

modate workmen and loading it with tools, material and supplies. This barge was towed by a steam towboat to different points where it was required.

An arrangement was also made with representatives of the Louisville, New Orleans and Texas, the Texas and Pacific, and the Southern Pacific railroads, all of which were provided with labor, tools and material and facilities for rapid transportation, by which they were to do such work as might be immediately necessary, and which could not be attended to at proper time by the outfit in charge of this office.

The following table shows the protection and repair work done below Red River, right bank:

Localities.	Nature of protection.
Red River Landing (765.3 R)	Removal of stumps, stopping craw-fish holes, restoring embankment at road crossings, etc.
Nina (806.5 R)	Wave wash on old front line stopped with sacks.
Highland (815.5 R)	Old front line repaired at road crossings.
Evergreen (857 R)	Old front line revetted with lumber.
Left bank.	
Longwood (847 L)	Board revetment.
Davenport (838 L)	Do.
Saint Gabriel (862 L)	Board and sack revetment.
Southwood (875 L)	Do.
Ashland (878 L)	Do.
Dicharry (882 L)	Do.
Melancon (888 L)	Do.

No protection work was done below the city of New Orleans. Requests were received for assistance in maintaining the levees in that part of the district, but at that time the funds available were limited and as all indications pointed to very high water, it was deemed expedient to reserve the money for probably greater danger in the upper parts of the district. An inspection was made of the levees down as far as the forts early in April after the additional allotments became available, but at that time the river had fallen slightly, all the levees were secure and the danger was practically over.

It is urgently recommended that sufficient funds be made available for putting all the United States levees in this district in proper condition of repair as early as practicable before next high water.

The work of this kind which is necessary consists of clearing the levees of trees, brush, and all other vegetation except grass; restoring the embankment where washed by rain or the action of waves, or worn down by unauthorized traffic; repairing all weak places due to craw-fish holes, "sand-boils" or other causes; and in certain special cases raising the grade. The above does not, however, contemplate any general enlargement or raising of the embankment, but only what may properly be included under repairs, care, and maintenance of the existing works and raising certain places where the line is seriously weak, due to local deficiency in height. If this work were done now time would be afforded for the earth to become solidified and sodded over before high water, and a degree of security and relief from anxiety would be afforded which no expenditure of money during high water could secure, and the results from money so applied as compared to those following from an equal expenditure during the time of danger would be incomparably greater.

Assuming that the balances of the amounts reserved for the care and maintenance of the levees are applicable as above, the additional funds needed for this work are as follows:

Tensas Basin:	
Estimate	$12,600.00
On hand	8,800.00
Amount needed	3,400.00
Right bank below Red River:	
Estimate	5,000.00
On hand	5,195.00
Left bank below Red River:	
Estimate	5,000.00
On hand	1,430.00
Amount needed	3,570.00
Total amount needed	6,970.00

The following amounts were expended for care and maintenance of levees during high water:

Tensas Basin	$3,010.98
Right bank below Red River	2,203.75
Left bank below Red River	3,723.94
Total	8,938.67

There were no expenditures from the last allotment for protection of levees from threatened danger from high water, and the entire allotment, $107,938, is still in hand.

After the new levee lines were staked out preparatory to beginning work, Assistant Engineer Douglas was assigned to the local charge of all levee work above the mouth of the Red River, and Assistant Engineer Hardee to similar duty for that part of the district below Red River. Their reports are appended hereto.

IMPROVING MISSISSIPPI RIVER (NO LIMIT).

Money statement.

(*a*) Levees, Tensas Front:

July 1, 1890, balance unexpended		$29,117.42
June 30, 1891, amount expended during fiscal year	$16,581.89	
June 30, 1891, amount expended during fiscal year for protection of levees, Tensas Basin	12,535.53	
		29,117.42

(*b*) Levees, Tensas Basin:

Amount allotted from act approved September 19, 1890	199,500.00
Amount reallotted from act of August 5, 1886	21.00
	199,521.00
June 30, 1891, amount expended during fiscal year	81,988.84
July 1, 1891, balance unexpended	117,532.16
July 1, 1891, amount covered by uncompleted contracts	51,010.90
July 1, 1891, balance available	66,521.26
Amount that can be profitably expended during fiscal year ending June 30, 1893	125,000.00

(*c*) Levees, right bank, below Red River:

Amount appropriated by act approved September 19, 1890	123,975.00
June 30, 1891, amount expended during fiscal year	107,464.85
July 1, 1891, balance unexpended	16,510.15
July 1, 1891, amount covered by uncompleted contracts	9,927.58
July 1, 1891, balance available	6,582.57
Amount that can be profitably expended in fiscal year ending June 30, 1893	160,000.00

(*d*) Levees, left bank, below Red River:

Amount appropriated by act approved September 19, 1890	89,775.00
June 30, 1891, amount expended during fiscal year	84,057.86
July 1, 1891, balance unexpended	5,717.14
Amount that can be profitably expended in fiscal year ending June 30, 1893	65,000.00

(*e*) Protection of levees, fourth district:

July 1, 1890, balance unexpended		18,160.1
June 30, 1891, amount expended during the fiscal year	$8,160.13	
Amount transferred to third district	10,000.00	
		18,160.1

(*f*) Protection of levees, Tensas Basin:

Amount allotted from act of September 19, 1890	51,000.(
June 30, 1891, amount expended during fiscal year	3,010.!
July 1, 1891, balance unexpended	47,989.

Amount that can be profitably expended in fiscal year ending June 30, 1893.	$3,400.00
(*g*) Protection of levees, right bank, below Red River:	
Amount allotted from act approved September 19, 1890	50,275.00
June 30, 1891, amount expended during fiscal year	2,203.75
July 1, 1891, balance available	48,071.25
(*h*) Protection of levees, left bank, below Red River:	
Amount allotted from act approved September 19, 1890	28,413.00
June 30, 1891, amount expended during fiscal year	3,723.94
July 1, 1891, balance unexpended	24,689.06
Amount that can be profitably expended in fiscal year ending June 30, 1893.	3,570.00

SURVEYS, GAUGES, AND OBSERVATIONS.

In addition to the surveys made in connection with works for which there were specific allotments, surveys of a number of alternative lines for new levees at Kempe (659 R.) and at Hardscrabble (640 R.) were made. These are both United States levees, and the danger of their being breached by caving banks is so imminent that provision must be made for the new lines, either by the United States or the State authorities, before the next high water, in order to render Tensas Basin safe from overflow.

Surveys to determine the continuous profiles of all levees in this district are very much needed. There was no time to undertake this work before establishing the grades of the levees which were built by this office during the past year, and their grades were therefore not fixed in accordance with any very definite system as the data and the time necessary for formulating such a system were wanting. The expediency of making such surveys hereafter will be influenced by the policy which may govern levee construction in the future. It is estimated that the preparation of complete levee profiles for the district, including new surveys and necessary copying of information on file in the State engineer's office will cost about $1,700.

All the gauge stations heretofore established in this district were maintained, and by direction of the commission the following new stations were established:

Sugar House gauge, at head of Turnbull Island, above the Red River Dam. Established November 27, 1890.

Fort Jackson gauge, established February 23, 1891.

Owing to the inaccessibility of this latter station, and a change of gauge-keepers soon after it was established, the record up to the present time can not be said to have been entirely satisfactory; but the apparently abnormal variations are attributable, in part at least, to the effect of winds and tides in the Gulf. To be of value it is believed that a recording tide gauge should be established here, and such a gauge at New Orleans would also give more complete information than is afforded by the present system of only two readings a day.

Six new bulletin boards of the pattern adopted by the Commission have been built to replace existing ones where extensive repairs or new bulletin boards are required.

The following table shows the highest and lowest readings at the various stations compared with last year's record:

Highest gauge readings.

Stations.	1889-'90.		1890-'91.		Difference.
	Date.	Reading.	Date.	Reading.	
Mississippi River:					
St. Joseph, La	Apr. 23, 1890	45.15	Apr. 13, 1891	43.70	1.45
Natchez, Miss	Apr. 23, 1890	48.60	Apr. 11, 1891	46.50	2.10
Red River Landing, La	....do	48.80	Apr. 27, 1891	45.48	3.32
Red River:					
Barbre Landing, La	....do	49.70	Apr. 25, 1891	45.65	4.05
Sugar House, La			Apr, 30, 1891	45.99	
Atchafalaya River:					
Melville, La	Apr. 28, 1890	35.4	Apr. 19, to May 8.	33.7	1.7
Simmsport, La	Apr. 22-23, 1890.	45.50	Apr. 26, 1891	43.32	2.18
Mississippi River:					
Bayou Sara, La	Apr. 21, 1890	41.2	Apr. 29, 1891	38.8	2.4
Baton Rouge, La	....do	36.75	May 3, 1891	35.55	1.20
Plaquemine, La	Apr. 22, 1890	31.9	Apr. 29, 1891	31.0	.9
College Point, La	Mar. 16, 1890	23.90	Mar. 16, 1891	23.40	.50
Carrollton, La	Mar. 17, 1890	16.10	....do	16.00	.10
Fort Jackson, La			....do	6.15	

Lowest gauge readings.

Stations.	1889-'90.		1890-'91.		Difference.
	Date.	Reading.	Date.	Reading.	
Mississippi River:					
St. Joseph, La	Oct. 31, 1889	—3.95	June 3, 1891	15.35	19.30
Natchez, Miss	Nov. 4, 1889	2.70	June 12, 1891	20.80	18.10
Red River Landing, La	....do	2.40	June 13, 1891	20.62	18.22
Red River:					
Barbre Landing, La	Nov. 7, 1889	2.4	June 14, 1891	20.8	18.40
Sugar House, La			....do	19.97	
Atchafalaya River:					
Melville, La	Nov. 6, 1889	4.5	....do	20.6	16.10
Simmsport, La	Nov. 7, 1889	2.0	....do	19.30	17.30
Mississippi River:					
Bayou Sara, La	Nov. 3, 1889	—2.1	....do	13.6	15.7
Baton Rouge, La	Oct. 28, 1889	2.50	....do	14.0	11.50
Plaquemine, La	Nov. 5, 1889	1.5	....do	10.9	9.4
College Point, La	....do	.57	....do	7.88	7.31
Carrollton, La	Oct. 28, 1889	.40	....do	4.95	4.55
Fort Jackson, La			June 5, 1891	2.6	

Owing to the great pressure of levee work and the absorbing duties incident to the recent high water the gauge service has not received the attention during the past year that should have been given to it.

The gauges on the Mississippi within the limits of the district are now under two separate administrations, and the contrast in the degree of efficiency attained during the past year can not be claimed to be in favor of this office. It is recommended that, if practicable, arrangements be made to place all these gauges under one charge.

AMES CREVASSE.

This crevasse occurred at a point in the levee on the right bank between the two spur dikes constructed in the Greenville Bend in 1889 and 1890. It was directly opposite the Audubon Park, sixth district, city of New Orleans.

The levee here was generally an efficient embankment having a crown of 8 feet, a slope on the river side of 3 to 1, and on the land side of 2 to 1. It was well sodded and the front slope had been protected from wave wash by a board revetment built some time previous to the high water season. There was a batture about 60 feet wide adjacent to the break, over which the water stood at a depth of about 3 feet. The crown of the levee had a height above the batture of 5 feet, and above the ground in the rear of about 10 feet. The water was within 2 feet of the crown at the time the break occurred. In October, 1890, an iron pipe had been placed through the levee several feet below the surface of the ground on the land side, and it is believed that the crevasse was caused by the careless manner in which the earth was replaced over the pipe, as the break started through the crown and at first had a depth of only 3 feet.

The break occurred in the evening on March 16, and on the 18th measurement showed its width to be 164 feet. Daily measurements were made until June 3, 1890, when it had attained a width of 1,665 feet.

Gauges were also established to determine the effect upon the height of the river in the vicinity and the height of the backwater.

A discharge section was established below and measurements taken with a view to determining the discharge of the crevasse by deducting the discharge of the section below from that found at the Carrollton section where the discharge was also being taken at the same time, since it was not practicable to get reliable discharge measurements directly, owing to the velocity of the current and the irregularity of the crevasse sections.

The results of the measurements show such abnormal variations in the discharge at the lower section that they can not be accepted as reliable. The discharge of the crevasse is estimated to have been about 91,000 cubic feet per second between April 6 and April 14.

The crevasse undoubtedly produced considerable disturbance in the current at the lower discharge section, as is indicated by the formation of a bar in the river near that point where there was formerly deep water.

An attempt was made to establish an observation station in the throat of the crevasse. Three telegraph poles about 44 feet long were securely fastened together at the top by bolts and wire lashing, the butts being separated and held in place by

braces or cross pieces fastened to the poles by strong iron clevises and dowels and lashings of wire. The structure had a triangular base 35 feet on a side and to the foot of each pole were secured three car wheels weighing 558 pounds each to serve as ballast and to give the stand a bearing in the soft mud. This tripod was built on a barge and then moved out over the end until the outboard portion overbalanced that on deck, the top being lashed to the deck to prevent it from tipping. This barge was then taken in tow by a tug having a 500-foot towline and manœuvered till the barge was drawn into the crevasse, while the tug being clear of the swiftest current, could hold it in position by steaming ahead. When in the proper position the lashing was cut and the tripod launched overboard, landing upright in the deepest part of the crevasse, where it stood in about 11 feet of water and a swift current. One of the logs was broken by the shock of the fall near the top, but the structure as a whole remained in position and otherwise uninjured. Though by the time there was an opportunity to place the tripod the water had fallen and the current diminished materially, and there was no need of it as an observation station, the experiment showed that it would be quite possible to successfully plant such structures in a flowing crevasse without difficulty.

The crevasse completely interrupted three railroads, the Texas and Pacific, the Southern Pacific, and the Grand Isle and Fort Jackson. The latter is a local road and no attempt was made to reëstablish traffic on it, but the service of the other roads was kept up in an imperfect manner by transfer boats to a point 17 miles above the city, at which point the railroad tracks were only partially submerged by the backwater from the crevasse, and by means of trestlework and constant repairs admitted of travel.

The following data concerning the damage caused by this crevasse was compiled by Assistant Engineer W. J. Hardee. The estimates are, of course, approximate and they were made from information collected from local officials, railroad companies, and other sources which may be considered reliable, though greater accuracy could be attained with more time for careful surveys and inquiry.

		Acres.
Total overflowed		1,396,224
Cultivated land overflowed:		
Sugar	62,914	
Corn	48,653	
Rice	39,733	
Total		151,300

	Miles.
Railroad track in overflowed section	146
Track entirely destroyed	2
Track on which traffic was suspended	84
Track partially destroyed, had to be cribbed up above water	60

Estimated damage.

Agriculture	$7,683,793
Live stock	2,700
Drainage and canals	64,700
Buildings and fences	92,350
Railroads	533,400
Total	8,376,943

The immediate effect of the break was a general relief from anxiety in this city at a time when the river was very little lower than the highest level it has ever reached since authoritative records have been kept, and from the date of the crevasse, when the Carrollton gauge stood at 16 feet, there was a steady fall.

What the results would have been had a similar crevasse taken place on the opposite side of the river might form an interesting subject for speculation.

There were only two other openings in the levees of this district during the flood, the one at Henderson (713 R) which was a break made in 1890 and not closed before high water, and the one at Ferriday (693 R) which occurred on the night of May 5, 1891, after the water had fallen considerably.

Both were local in their effects and unimportant and no discharge measurements were made at either. At Henderson the gap was 1,075 feet in width and the maximum discharge may have been about 26,000 cubic feet per second. At Ferriday the opening was 97 feet wide before it was closed and the estimated discharge was about 3,400 cubic feet per second.

The latter break was closed by sacks filled with earth.

When it became evident that a large flood was probable, discharge measurements were undertaken at Warrenton, Red River Landing and Carrollton, as well as at Simmsport on the Atchafalaya. The section at Warrenton proved unreliable on account of cross currents and eddies, and as no good section could be found near the party was moved to Natchez.

The following table gives the maximum discharge at each station and the dates, for 1890 and 1891:

Station.	1890. Greatest discharge.	Date.	1891. Greatest discharge.	Date.
Mississippi:	*Cubic feet.*		*Cubic feet.*	
Warrenton	1,354,725	Apr. 12	....	....
Natchez	1,396,492	Mar. 17	1,528,869.825	Mar. 30
Red River Landing	1,487,362	Mar. 7	1,159,852.177	Apr. 2
Carrollton	1,286,008	Mar. 20	1,217,807.35	Apr. 9
Atchafalaya:				
Simmsport	480,708	May 12	820,545.792	Apr. 11

Details of the results are given in the reports of the assistants who made the several observations.

The sections of the river at the Morganza and Nita crevasses were resounded between June 4 and June 23, 1891. The results of these soundings in comparison with soundings previously made are shown on accompanying charts.

The estimate for surveys, gauges, and observations for the ensuing year is for salaries of gauge-keepers, expenses of maintaining gauges, expenses of discharge observations and expenses of surveys for which no specific allotment is made is $10,000.

IMPROVING MISSISSIPPI RIVER (NO LIMIT).

Money statement.

(*a*) Surveys, examinations, and inspections:

July 1, 1890, balance unexpended	$1,507.41
June 30, 1891, amount expended during fiscal year	1,507.41

(*b*) Gauges, fourth district:

July 1, 1890, balance unexpended	400.02
June 30, 1891, amount expended during fiscal year	400.02

(*c*) Surveys, gauges, and observations:

Amount allotted from act approved September 19, 1890	12,000.00
June 30, 1891, amount expended during fiscal year	6,299.50
July 1, 1891, amount available	5,700.50
Amount that can be profitably expended in fiscal year ending June 30, 1893	10,000.00

Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.

COMMERCIAL STATISTICS.

The following commercial statistics for this district were compiled by Assistant Engineer W. J. Hardee.

The statistics relating to the foreign commerce of the port of New Orleans were kindly furnished by Hon. H. C. Warmoth, collector of the port.

Statement showing the approximate receipts and shipments of freight by river from June 1, 1890, to June 1, 1891, compiled from information derived from the commercial exchanges of the representative towns, and the several business houses and landings where the steamboats receive and discharge cargoes, and from the records of the custom-house port of New Orleans.

NATCHEZ, MISSISSIPPI.

Receipts.

Number of steamboats in the trade	
Number of times arrived	8.
Number of barges	
Total cargo arrived (tons)	106,9
Value of same	$1,734,027.

ARTICLES OF CARGO.

Cotton ....bales..	15, 500	Coal ....bushels..	1, 250, 000
Lumber..........feet, B. M..	7, 000, 000	Sacks, empty ......bundles..	1, 150
Wood................cords..	960	Flour...............barrels..	19, 156
Corn meal...........barrels..	37, 482	Corn.................sacks..	65, 840
Oats ....sacks..	101, 450	Wet barrels........number..	987
Bran....................do....	13, 189	Sash, doors and blinds, packages.....................	769
Wrapping paper..packages..	605	Groceries ....packages..	18, 780
Hardware.............do....	10, 374	Miscellaneous.........do....	1, 150
Wooden ware ....do....	7, 628		
Cotton seed..........sacks..	65, 307		

Shipments.

Number of steamboats in the trade	38
Number of times departed	717
Total cargo shipped (tons)	28, 104
Value of same	$1, 095, 890

ARTICLES OF CARGO.

Cotton ....bales..	10, 527	Miscellaneous ....packages..	1, 052
Cotton-seed oil .....gallons..	154, 677	Cotton cloth ....yards..	764, 575
Cotton linters ......pounds..	176, 775	Cotton seed meal .....sacks..	12,305
Lumber ....feet, B. M..	1, 490, 600	Sacks, empty ......number..	2, 084
Ice.....................tons..	1, 998	Shingles ....do....	910, 500
Flour................barrels..	14, 876	Corn meal...........barrels..	31, 462
Corn..................sacks..	42, 842	Oats ....sacks..	73, 197
Wet barrels.........number..	944	Bran...................do....	7, 670
Sash, doors and blinds, packages.....................	653	Wrapping paper...bundles..	869
Groceries.........packages..	15, 683	Hardware ....packages..	8, 558
Cotton batting ....bales..	583	Wooden ware..........do....	5,976
		Bricks ....number..	215, 600

RECAPITULATION FOR NATCHEZ, MISSISSIPPI.

Total cargo received and shipped (tons)	135, 065
Total value of cargo received and shipped	$2, 829, 917

VIDALIA, LOUISIANA.

Number of steamboats in trade	38
Number of times they have landed	819
Number of barges	2
Total cargo received and shipped (tons)	12, 392
Total value of cargo received and shipped	$781, 976. 75

ARTICLES OF CARGO.

Cotton ....bales..	12, 560	Cotton seed..........sacks..	58, 400
Cross ties..........number..	5, 147	Bran ....do....	900
Corn..................sacks..	12, 519	Oats ....do....	15, 465
Corn meal..........barrels..	5, 314	Flour ....barrels..	2, 758
Hay ....bales..	1, 870	Liquors ....do....	150
Miscellaneous ....packages..	7, 200	Meat (salt) ....boxes..	175
Furniture ....do....	3, 500	Sugar ....barrels..	410
Molasses ....barrels..	325	Groceries ....packages..	3, 325
Lime ....do....	180	Hardware ....do....	1, 275
Coal ....bushels..	24, 000	Lumber..........feet, B. M..	196, 750

BAYOU SARA, LOUISIANA.

Receipts.

Number of steamboats in the trade	48
Number of times they arrived	1,019
Number of barges	17
Total cargo arrived (tons)	29,321
Value of same	$1,113,719

ARTICLES OF CARGO.

Cotton	bales	5,560	Coal	bushels	225,000
Potatoes	barrels	2,218	Corn meal	barrels	25,140
Flour	do	11,509	Pork	do	7,621
Corn	sacks	21,525	Oats	sacks	37,058
Meat (salt)	pounds	1,479,870	Soap	pounds	10,800
Lard	do	64,625	Beer	casks	1,545
Bagging	rolls	5,000	Ties	bundles	6,500
Hay	bales	6,241	Lime	barrels	420
Bran	sacks	3,278	Grits	do	8,596
Soda pop	boxes	480	Groceries	packages	18,000
Furniture	packages	2,160	Hardware	do	5,000
Wooden ware	do	20,985	Molasses	barrels	510
Sugar	barrels	1,600	Coffee	sacks	1,275
Rice	do	350	Salt	do	1,200
Tobacco	pounds	40,700	Miscellaneous	packages	7,000
Fertilizers	tons	115	Wire	coils	4,500
Ice	do	800	Cement	barrels	500
Lumber	feet, B. M	500,000			

Shipments.

Number of steamboats in the trade	48
Number of times departed	747
Total cargo shipped (tons)	19,940
Value of same	$1,193,396.00

ARTICLES OF CARGO.

Cotton	bales	18,340	Cotton seed	sacks	60,000
Lumber	feet, B. M	250,000	Potatoes	barrels	1,286
Corn meal	barrels	4,625	Flour	do	2,150
Pork	do	1,980	Corn	sacks	11,300
Oats	sacks	20,600	Meat (salt)	pounds	225,000
Soap	pounds	2,500	Lard	do	12,500
Bagging	rolls	2,000	Ties	bundles	2,800
Hay	bales	3,500	Lime	barrels	225
Cement	barrels	50	Bran	sacks	1,200
Grits	do	7,175	Groceries	packages	2,879
Furniture	packages	600	Hardware	tons	45
Wooden ware	do	12,600	Molasses	barrels	175
Sugar	barrels	600	Coffee	sacks	525
Rice	do	200	Salt	do	480
Tobacco	pounds	10,000	Miscellaneous	packages	2,165
Wire	coils	1,125	Beer	casks	800
Ice	tons	600	Coal	bushels	120,000

RECAPITULATION FOR BAYOU SARA, LOUISIANA.

Total cargo received (tons)	29,321
Total value of same	$1,113,719
Total cargo shipped (tons)	19,940
Total value of same	$1,193,396
Total cargo received and shipped (tons)	49,261
Total value of same	$2,307,115

BATON ROUGE, LOUISIANA.

Receipts.

Number of steamboats in the trade	49
Number of times they arrived	895
Number of barges	108
Total cargo received (tons)	23,313
Total value of same	$2,257,360

ARTICLES OF CARGO.

Cotton	bales	1,650	Cotton seed	tons	2,889
Lumber	feet, B. M.	13,000,000	Coal	bushels	3,750,000
Potatoes	barrel	4,000	Corn meal	barrels	42,650
Flour	do	45,100	Oats	sacks	80,000
Corn	sacks	55,700	Bran	do	12,500
Hay	bales	9,000	Oils	barrels	318
Pork and mess beef	barrels	610	Liquors	do	150
Vinegar	do	135	Hardware	packages	24,670
Wrapping paper	bundles	600	Groceries	do	45,500
Wooden ware	packages	31,540	Miscellaneous	do	4,980
Bagging	rolls	2,800	Ties	bundles	7,325
Sugar	barrels	1,925	Molasses	barrels	2,150
Rice	do	1,410	Coffee	sacks	1,142
Tobacco	pounds	285,600	Dry goods	packages	3,200
Moss	bales	1,200	Wool	pounds	1,475
Hides	number	1,995	Cabbages	crates	300

Shipments.

Number of steamboats in the trade	49
Number of times departed	693
Total cargo shipped (tons)	60,787
Total value of same	$1,737,434

ARTICLES OF CARGO.

Cotton	bales	12,976	Cotton seed	sacks	15,500
Cotton-seed meal	sacks	17,819	Cotton-seed oil	gallons	232,064
Cotton linters	pounds	100,219	Lumber	feet, B. M.	4,750,000
Shingles	number	25,000,000	Brick	number	4,250,000
Moss	bales	9,975	Wool	pounds	4,260
Hides	number	15,320	Cabbages	crates	800
Potatoes	barrels	5,987	Ice	tons	125
Corn meal	barrels	16,250	Flour	barrels	19,975
Oats	sacks	35,100	Corn	sacks	43,760
Bran	sacks	2,500	Hay	bales	4,500
Pork and mess beef	barrels	325	Vinegar	barrels	76
Oils	barrels	246	Liquors	barrels	75
Wrapping paper	packages	250	Hardware	packages	11,125
Groceries	packages	24,867	Wooden ware	packages	19,250
Miscellaneous	packages	3,000	Bagging	rolls	950
Ties	bundles	2,645	Sugar	barrels	2,475
Molasses	barrels	3,790	Rice	barrels	625
Coffee	sacks	537	Tobacco	pounds	21,750
Dry goods	packages	1,100			

RECAPITULATION FOR BATON ROUGE, LOUISIANA.

Total cargo received (tons)	23,313
Total value of same	$2,257,360
Total cargo shipped (tons)	60,787
Total value of same	$1,737,434
Total cargo received and shipped (tons)	84,100
Total value of same	$3,994,794

PLAQUEMINE, LOUISIANA.

Receipts.

Number of steamboats in the trade	50
Number of times they arrived	453
Number of barges	52
Total cargo arrived (tons)	61,110
Total value of same	$819,176

ARTICLES OF CARGO.

Potatoes	barrels	2,650	Onions	barrels	820
Corn meal	do	8,154	Flour	do	12,500
Grits	do	3,478	Hay	bales	2,000
Corn	sacks	18,700	Oats	sacks	14,500
Bran (wheat)	do	5,000	Bran (rice)	sacks	2,100
Groceries	packages	53,800	Hardware	packages	4,225
Wooden ware	do	2,000	Sugar	barrels	2,150
Molasses	barrels	350	Rice	do	1,200
Coffee	sacks	1,315	Liquors	do	375
Vinegar	barrels	250	Oils	do	330
Dry goods	packages	1,495	Miscellaneous	packages	3,980
Lime	barrels	975	Beef and mess pork	barrels	510
Meat (salt)	boxes	1,423	Fruits	packages	1,705
Oysters	barrels	2,500	Machinery (tons)		40
Crockery	packages	213	Furniture		2,481
Coal	bushels	1,250,000	Cotton-seed meal	sacks	5,000
Moss	bales	110			

Shipments.

Number of steamboats in the trade	50
Number of times departed	388
Number of barges	11
Total cargo shipped (tons)	57,899
Total value of same	$596,899

ARTICLES OF CARGO.

Lumber	feet, B. M.	11,250,000	Liquors	barrels	52
Shingles	number	50,000,000	Dry goods	packages	137
Sugar	hogsheads	1,350	Fruits	do	200
Molasses	barrels	3,000	Miscellaneous	do	1,250
Moss	bales	6,280	Honey	barrels	30
Hides	number	12,500	Flour	do	4,250
Fish	pounds	14,000	Hay	bales	200
Potatoes	barrels	687	Oats	sacks	3,600
Onions	do	375	Groceries	packages	6,500
Corn meal	do	2,980	Wooden ware	do	850
Grits	do	2,700	Coffee	sacks	620
Corn	sacks	1,250	Oils	barrels	25
Bran	do	160	Furniture	packages	400
Hardware	packages	1,647	Salt meats	boxes	150
Rice	barrels	400			

RECAPITULATION FOR PLAQUEMINE, LOUISIANA.

Total cargo received (tons)	61,110
Total value of same	$819,176
Total cargo shipped (tons)	57,899
Total value of same	$596,899
Total cargo received and shipped (tons)	119,009
Total value of same	$1,416,075

DONALDSONVILLE, LOUISIANA.

Receipts.

Number of steamboats in the trade	41
Number of times they arrived	963
Number of barges	104
Total cargo received (tons)	105,172
Total value of same	$929,570

ARTICLES OF CARGO.

Corn meal ....pounds..	675	Flour............barrels..	610
Grits ....barrels..	830	Meat (salt) ....boxes..	450
Liquors ....do....	400	Oils ....barrels..	645
Vinegar ....do....	98	Corn..................sacks..	11,500
Oats ....sacks..	16,700	Hay ....bales..	2,000
Bran (wheat) ....do....	100	Bran (rice) ....sacks..	100
Groceries.........packages..	2,100	Hardware ....packages..	110
Wooden ware ....do....	987	Dry goods ....do....	200
Crockery ....do....	150	Lime ....barrels..	1,000
Miscellaneous ....do....	1,125	Fruits............packages..	980
Oysters ....barrels..	360	Lumber ....feet, B. M..	60,000
Potatoes ....do....	1,250	Onions ....barrels..	340
Acids (carboys)	1,000	Coal ....bushels..	2,500,000
Sugar ....barrels..	15,000	Molasses ....barrels..	4,000
Rice ....do....	2,000	Coffee ....sacks..	840
Charcoal.............sacks..	600		

Shipments.

Number of steamboats in the trade	41
Number of times they departed	591
Total cargo shipped (tons)	6,059
Total value of same	$482,700

ARTICLES OF CARGO.

Sugar ....barrels..	20,000	Molasses ....barrels..	12,000
Hides..................number..	200	Miscellaneous ....packages..	1,150

RECAPITULATION FOR DONALDSONVILLE, LOUISIANA.

Total cargo received (tons)	105,172
Total value of same	$929,570
Total cargo shipped	6,059
Total value of same	$482,700
Total cargo received and shipped (tons)	111,231
Total value of same	$1,412,270

The above towns are, strictly speaking "way points," and not termini, and the net tonnage or carrying capacity of the steamboats that do business at those places is not given, as it would not show the proper relation between what would then be made the possible tonnage and the actual tonnage brought.

All New Orleans steamboats are counted "arrived" when they stop on their journey up the river, and "departed" when they stop on their way down to New Orleans.

The St. Louis and Ohio River steamboats are counted arrived when they stop on their journey down the river, and departed when they stop on their way up stream.

Owing to the obscure records obtainable, many articles of a like character are styled under one head.

Statement showing the amount and value of commerce passing out of Red River and its tributaries through Old River into the Mississippi River, compiled by Mr. W. J. Hardee, assistant engineer, from the river column of the New Orleans Daily States, and from the assistance furnished by the commercial exchanges of New Orleans, Louisiana.

[The period embraced by this report extends from June 1, 1890, to June 1, 1891.]

STATEMENT.

Number of steamboats	17
Trips made by them	501
Net tonnage of same	101,604
Number of barges	24
Net tonnage of same	14,400
Total tonnage of steamboats and barges	116,004
Total cargo brought (tons)	92,232
Value of same	$10,951,108

ARTICLES OF CARGO.

Bones ..... sacks..	274	Bottles (empty) ..... barrels..	1,000
Cattle ..... head..	237	Cabbage ..... crates..	228
Cotton ..... bales..	189,260	Cotton-seed oil ..... barrels..	4,241
Cotton seed ..... sacks..	435,045	Excelsior ..... bales..	1,512
Eggs ..... packages..	2,605	Hides ..... packages..	1,675
Hides ..... loose..	563	Honey ..... barrels..	14
Hogs ..... number..	599	Iron ware ..... packages..	252
Horses or mules ..... head..	35	Moss ..... bales..	698
Lumber ..... feet, B. M...	43,702	Miscellaneous ..... packages..	137
Molasses ..... barrels..	14,401	Potatoes ..... barrels..	548
Pecans ..... do....	123	Poultry ..... coops..	75
Potatoes ..... sacks..	1,050	Peas ..... barrels..	52
Pitch ..... barrels..	52	Rice ..... sacks..	22,495
Peas ..... sacks..	119	Skins ..... packages..	22
Sheep ..... head..	41	Sugar ..... barrels..	32,631
Sugar ..... hogsheads..	3,612	Seed cotton ..... sacks..	37
Straw ..... bales..	715	Tallow ..... barrels..	73
Staves (oak) ..... number..	92,296	Wood ..... cords..	1,970
Wool ..... bags..	520		

This does not include the upstream freights, which must be nearly equal to the downstream ones.

Statement showing the river arrivals at New Orleans, La., from June 1, 1890, to June 1, 1891, compiled by Mr. W. J. Hardee, assistant engineer, from the river column of the New Orleans Daily States and from assistance furnished by the commercial exchanges of New Orleans, La.

ABOVE THE CITY.

Steamboats (number)	51
Trips made by them	1,417
Net tonnage of same	665,610
Towboats (number)	45
Trips made by them	134
Net tonnage of same	51,810
Barges (number)	929
Net tonnage of same	418,050
Number of luggers (sailing)	18
Trips made by them	162
Net tonnage of same	4,860
Total tonnage (steamboats, towboats, barges, and luggers)	1,140,350
Total cargo brought (tons)	1,343,061
Value of same	$54,332,685

BELOW THE CITY.

Steamboats in local trade	6
Trips made by them	321
Net tonnage of same	31,039
Luggers (sailing) in local trade	218
Trips made by them	4,250
Net tonnage of same	130,800
Total tonnage (steamboats and luggers)	161,839
Total cargo brought (tons)	22,422
Value of same	$1,729,092

RECAPITULATION.

Total arrivals (steamboats, towboats, barges, and luggers) above and below	7,193
Total net tonnage, above and below	1,502,169
Total cargo brought, above and below (tons)	1,365,483
Value of same	$56,061,777

ARTICLES OF CARGO.

Acids.......carboys..	3,939	Groceries.......packages..	3,598
Apples.......barrels..	305	Grits.......barrels..	49,672
Ammonia.......drums..	312	Glycerine.......do....	118
Apples.......dried..	327	Glucose.......do....	915
Buckets.......dozen..	1,778	Glue.......do....	43
Baking powder.......boxes..	265	Hams.......cases..	1,581
Barley.......sacks..	50	Hubs.......bundles..	61
Buggies.......number..	109	Hair.......bales..	1,660
Beef.......barrels..	108	Hay.......do....	5,960
Beer.......casks..	1,405	Hay.......half bales..	9,425
Bagging.......rolls..	37,625	Hay.......quarter bales..	6,744
Barrels, empty.......number..	2,610	Hogs.......head..	842
Beans....barrels and sacks..	490	Hoop-poles.......number..	27,941
Bungs.......barrels..	161	Hominy.......barrels..	220
Bacon.......boxes..	497	Handles.......bundles..	4,841
Bitters.......do....	6,009	Horns.......sacks..	6
Bones.......sacks..	521	Hides.......loose..	527
Brushes.......boxes..	24	Honey.......barrels..	54
Blueing.......cases..	4	Horses and mules.......head..	448
Butter.......packages..	368	Hose.......packages..	15
Bran.......sacks..	78,708	Hinges.......barrels..	274
Broom corn.......bales..	1,695	Hardware.......packages..	22,580
Bricks, fire.......number..	50,620	Iron ware.......packages..	42,728
Bottles, empty.......barrels..	3,100	Ink.......boxes..	302
Brooms.......dozens..	422	Kraut.......barrels..	225
Clippings.......bales..	19	Kegs (empty).......number..	3,234
Clothespins.......boxes..	415	Lard.......packages..	95,944
Copper.......pounds..	4,580	Leather.......bundles..	395
Cork.......bags..	193	Laths.......number..	20,000
Cement.......barrels..	883	Lumber.......feet, B. M..	1,578,950
Carriages.......number..	15	Lead....pigs and packages..	592
Candles.......boxes..	582	Lye.......cases..	195
Cattle.......head..	619	Lime.......barrels..	3,065
Cabbage.......crates..	725	Mops.......dozen..	235
Canned goods.......boxes..	151	Mattresses, wire...number..	50
Carts.......number..	44	Mattresses.......do....	337
Cartridges...number cases..	200	Mucilage.......boxes..	64
Cider.......packages..	100	Machinery.......pieces..	128
Coal.......bushels..	10,766,200	Moss.......bales..	4,508
Coke.......do....	175,060	Molasses.......barrels..	275,559
Corn.......sacks..	180,693	Meat.......cases..	74
Corn.......bushels..	3,871,187	Meat.......bales..	2
Cotton-ties.......bundles..	142,800	Millet.......sacks..	721
Cotton seed.......sacks...	1,668,515	Malt.......do....	7,844
Cotton-seed ashes..barrels..	424	Mirrors.......boxes..	1,327
Cotton-seed oil.......do....	3,393	Miscellaneous....packages..	40,419
Cotton-seed meal....sacks..	122,191	Nails.......kegs..	35,745
Carbons.......boxes..	556	Oysters (shells)....barrels..	1,550,000
Corn meal.......barrels..	79,989	Oats.......sacks..	338,659
Corn meal.......sacks..	3,644	Oats (bulk).......bushels..	89,960
Cigars.......cases..	12	Oatmeal.......barrels..	326
Cotton linters.......bales..	231	Oil.......do....	4,926
Crockery.......packages..	2,517	Onions.......sacks..	14,731
Dry goods.......packages..	815	Onions.......barrels..	1,389
Drugs.......do....	4,230	Oranges.......do....	33,110
Excelsior.......bales..	2,800	Pipe.......packages..	2,520
Eggs.......packages..	7,223	Pecans.......barrels..	2,659
Earthenware.......crates..	471	Plows.......number..	6,867
Feed meal.......sacks..	6,568	Pickles.......barrels..	410
Fire-clay.......barrels..	630	Pickles.......cases..	10,821
Flour.......half barrels..	48,079	Potatoes.......sacks..	70,268
Flour.......barrels..	327,785	Potatoes.......barrels..	58,815
Flour sacks.......sacks..	3,626	Poultry.......coops..	564
Furniture.......packages..	33,659	Pork.......barrels..	2,191
Fruit, dried.......do....	28	Pitch.......do....	238
Flaxseed.......barrels..	118	Preserves.......cases..	321
Grindstones.......number..	5,371	Putty.......barrels..	150
Glassware.......packages..	17,431	Paint.......packages..	739

ARTICLES OF CARGO—Continued.

Peanuts ....bags..	2,070	Spikes................kegs..	203
Pease ....sacks..	245	Steel sheets ......packages..	1,755
Pease ....barrels..	211	Sawlogs (10-foot lengths). No count made of tonnage	94,080
Paper ....bundles..	6,855	Springs (car) ......number..	882
Rope ....coils..	616	Tallow ....barrels..	105
Rags ....bales..	32	Tobacco.............cases..	965
Rye..................sacks..	225	Tobacco.........hogsheads..	168
Rice ....barrels..	775	Toys ....packages..	221
Rice ....sacks..	263,111	Tinware ....do....	264
Shot..............pockets..	3,936	Tubs..................do....	42
Sheep ....number..	858	Trunks ....number..	1,669
Skins ....packages..	25	Varnish ....barrels..	62
Soap stock ....barrels..	237	Vegetables ....crates..	477
Sacks ....bales..	1,175	Vinegar ....barrels..	3,049
Shoes ....cases..	58	Wooden ware ....packages..	8,825
Seed (garden) ....packages..	869	Wax ....barrels..	5
Soap ....boxes..	14,353	Wool ....bags..	340
Staples ....kegs..	1,140	Wagon ware .....packages..	2,981
Starch...............boxes..	42,948	Wheat ....sacks..	944
Stone ....pieces..	72	Wheat (bulk)......bushels..	1,814,429
Spades and shovels.bundles..	1,024	Willow ware .....packages..	5,176
Sash weights ......number..	11,450	Whisky ....barrels..	259
Sugar ....hogsheads..	97,498	Whisky and wines....cases..	189
Sugar ....barrels..	417,405	White lead............do....	1,317
Screenings ....sacks..	605	White lead............kegs..	22,941
Staves (oak) ....number..	1,955,478	Wine...............barrels..	104
Saddlery ....packages..	2,425	Wire ....reels..	31,109
Syrup ....barrels..	6,007	Wheelbarrows .....bundles..	97
Showcases ....number..	237	Wood ....cords..	659
Straw.................bales..	4,661	Wheels ....bundles..	146
Seed, cotton ....sacks..	1,530	Zinc ....packages..	201
Stoves ....number..	3,775		

This list includes simply the freights brought to New Orleans by steamboats and barges on the Mississippi River and does not include the large and valuable freights that they take away. No record is kept of this, and it is impossible to furnish even a reasonably accurate estimate of its value. It would amount to a very large sum in the aggregate, probably more than 40 per cent. of the value of freights received at New Orleans.

Foreign commerce, port of New Orleans.

Vessels.	Entrances.		Clearances.	
	No.	*Tons.*	*No.*	*Tons.*
Steam	920	1,216,588	931	1,222,325
Sail	138	78,131	128	76,450
Estimate for June:				
Steam	74	86,340	60	43,170
Sail	15	5,663	6	2,333
Total	1,147	1,386,722	1,125	1,344,278

Total value of exports of foreign merchandise to foreign countries:	
For 11 months ending May 31, 1891	$854,588.00
Estimated for June, 1891	65,000.00
Total for fiscal year ending June 30, 1891	919,588.00
Total value of exports of domestic merchandise to foreign countries:	
For 11 months ending May 31, 1891	103,735,587.00
Estimated for June, 1891	3,000,000.00
Total for fiscal year ending June 30, 1891	106,735,587.00

Grand total of exports of foreign and domestic merchandise to foreign countries:	
For 11 months ending May 31, 1891	$104, 590, 175. 00
Estimated for June, 1891	3, 065, 000. 00
Total for fiscal year ending June 30, 1891	107, 655, 175. 00
Total value of imports (free) from foreign countries:	
For 11 months ending May 31, 1891	11, 074, 559. 00
Estimated for June, 1891	1, 200, 000. 00
Total for fiscal year ending June 30, 1891	12, 274, 559. 00
Total value of imports (dutiable) from foreign countries:	
For 11 months ending May 31, 1891	6, 340, 018. 00
Estimated for June, 1891	450, 000. 00
Total for fiscal year ending June 30, 1891	6, 790, 018. 00
Total value of imports (specie) from foreign countries:	
For 11 months ending May 31, 1891	503, 571. 00
Estimated for June, 1891	48, 000. 00
Total for fiscal year ending June 30, 1891	919, 588. 00
Grand total of imports (free, dutiable, and specie):	
For 11 months ending May 31, 1891	17, 918, 148. 00
Estimated for June, 1891	1, 698, 000. 00
Total for fiscal year ending June 30, 1891	19, 616, 148. 00
Duties collected:	
For 11 months ending May 31, 1891	1, 887, 385. 51
Estimated for June, 1891	125, 000. 00
Total for fiscal year ending June 30, 1891	2, 012, 385. 51
Miscellaneous collections:	
For 11 months ending May 31, 1891	59, 086. 04
Estimated for June, 1891	6, 000. 00
Total for fiscal year ending June 30, 1891	65, 086. 04

Approximate value of plant belonging to the United States and used upon the improvement of Mississippi River, fourth district.

Class of property.	Approximate value June 30, 1891.	Class of property.	Approximate value June 30, 1891.
Steamer General Newton	$12, 000	One warehouse barge	$200
Steam launch Ruby	4, 000	Fifteen row boats	200
Steam tug General Comstock	6, 500	Tools and appliances	16, 000
Steam tug Tilda	6, 000	Office furniture	1, 500
Steam launch Alaska	3, 500	Surveying instruments	2, 600
Steam launch No. 5	2, 000	Drawing instruments	200
One dredge boat	10, 000	Railway cars and tracks	1, 900
Four dump scows	12, 000	Miscellaneous, rock, lumber, etc	58, 000
Five quarter boats	12, 000		
Twenty-six barges	45, 000	Total	195, 800
One warehouse barge	2, 200		

NOTE.—One dredge boat borrowed from the third district, Mississippi River.

List of civil engineers employed on works of improvement in charge of First Lieut. John Millis, Corps of Engineers, during the fiscal year ending June 30, 1891, under river and harbor appropriation acts of August, 1886, August, 1888, and September, 1890.

Name and residence.	Time employed.	Compensation.	Where employed.	Works on which employed.
	Mos. dys.			
H. S. Douglas, New Orleans, La.	5 0	$175	New Orleans	New Orleans Harbor.
	7 0	200	Levees	Levees Tensas Basin.
W. G. Price, Simmsport, La.	5 0	175	Simmsport, La	Red and Atchafalaya rivers.
	7 0	200		
W. J. Hardee, New Orleans, La.	5 10	150	Fourth district Mississippi.	Surveys.
	6 20	175	Levees	Gauges and examinations levees right and left bank below Red River.
William Garvin	7 23	150	New Orleans, La	New Orleans Harbor.
G. Ed. Mott	7 0	140	Simmsport, La	Red and Atchafalaya rivers.

Accompanying and forming part of this report are the following reports of assistants:

Report of Assistant Engineer H. S. Douglas, on levees, survey at Natchez, Miss., and Vidalia, La., gauges.

Report of Assistant Engineer W. G. Price, on improvement of Red and Atchafalaya rivers, surveys, gauges, and observations.

Report of Assistant Engineer W. J. Hardee, on levees right and left banks below Red River.

Report of Assistant Engineer William Garvin, works of improvement, New Orleans Harbor, La., surveys, gauges, and observations, protection of levees right and left banks below Red River.

REPORT OF MR. H. S. DOUGLAS, ASSISTANT ENGINEER.

NEW ORLEANS, LA., *June 6, 1891.*

SIR: I have the honor to submit the following report upon the work of which I have had immediate charge during the year ending May 31, 1890:

LEVEES TENSAS BASIN.

CONSTRUCTION.

On June 1, 1890, no work was in progress. The United States levees were generally in fair condition, there being but one break in Lake Concordia Levee at Ferriday. There were two other gaps in the line of levees on the Tensas Front, but they were not in United States levees.

From November 9, 1890, to December 14, 1890, under allotments made by the Mississippi River Commission, the following levees were advertised, bids received, awards made, and contracts entered into:

	Cubic yards.
1. Bedford Levee (606 R.), about	30,500
2. Buckridge Levee (624 R.), about	100,000
3. Kempe Levee (659 R.), about	40,000
4. Gibson Landing Levee (683.5 R.), about	330,000
5. Ferriday Levee (693 R.), about	75,000
6. Arnauldia Levee (702 R.), about	20,000
7. Henderson Levee (712 R.), about	55,000
8. Deer Park Levee (722 R.) about	75,000

No further mention of Buckridge Levee will be made in this report as the contract was closed out under modification of original agreement, no construction work having been commenced.

The weather during January and February was very unfavorable, delaying operations considerably, The only levee completed in the original contract time was Arnauldia, which was a small affair, but all of the levees except Henderson to close actual gaps were completed either before or during high water. In general terms, considering the lateness of the season when work was commenced, and the early rise of the river, the results have been very satisfactory.

Levee surveys have been made at several points, either for present or prospective construction. In all 30 miles of levee line have been staked out and leveled, and 8.9 miles of old levee have been traversed to locate same on maps.

The organization and personnel employed has consisted of one assistant in local charge, one general inspector, and six resident inspectors. The duties of the assistant were the usual duties of an assistant engineer. The general inspector was under his immediate orders and acted as his assistant. The resident inspectors were stationed on the different levees to see that the specifications were observed and made regular reports as to the force employed, progress etc.

The general condition of levees on Tensas Basin, fourth district, at date of this report may be considered satisfactory and showing a steady improvement so far as restraining the river during high water is concerned. But one crevasse has occurred during the year, and it was an insignificant affair that was soon closed. This break was located in Lake Concordia Levee within 1,000 feet of the crevasses of 1884 and 1890. With this exception, and the Henderson Gap which the contractors failed to close before the high water of 1891, the line of levees is continuous from the head of the district to Fairview, the present terminus of the public system. The caving of the river banks will undoubtedly cause other gaps during the low-water season.

SUMMARY.

	Miles.
Length of levees under construction	6.7
Length completed to date	4.7
Length of levee lines surveyed	30
Old levees traversed	8.9

PROTECTION.

About February 15 the river had reached a dangerous height on the Tensas Front, and there were serious apprehensions of a destructive flood.

On February 16 the steamer *General Newton*, belonging to the work of improving the harbor at New Orleans, left for the threatened locality, to assist in such protection work as might be necessary. She had on board 20,000 sacks. Additional sacks were sent when required.

The boat arrived on the Tensas Front on February 19, and immediately commenced patrolling the river and inspecting the levees between Warrenton and Fairview. Such outfit as was considered necessary, in the way of wheelbarrows, shovels, and run plank, also a quarter boat and a small barge, were borrowed from the Atchafalaya work.

Later on, when the *Newton* was required elsewhere, the United States steamer *Thos. B. Florence*, kindly loaned by Capt. J. H. Willard, was engaged on the work.

Contrary to general expectation, the flood of 1891 did not reach the height of that of 1890 on the Tensas Front, fourth district. At Vicksburg it was 1 below, at St. Joseph, 1.3 below, and at Natchez 2.1 below.

The flood remained 94 days above the danger line at Vicksburg, and 68 days above the danger line at Natchez.

In consequence, although considerable work was required, no raising of levees was necessary. None of the levees were overtopped.

Commencing at the head of the district, the first levee requiring work was—

Point Pleasant Levee (621.5 R.).—For a distance of about one-half mile on Lake Palmyra this levee is exposed to wave wash, and it was protected with sacks, the cost for labor being about $151.70.

Hard Times Levee (631 R.).—A small amount of work was necessary at salient angle where the rapid current had commenced to wash away the embankment. The cost of labor for this work was $8.

Kempe Levee (659 R.).—This levee was the cause of more trouble, anxiety, and expense than any other portion of the line. The river rose over the bank before the new levee had been completed, and it was necessary to build a small protection levee to hold out the river until the main line was completed. The attempt was successful. The new main levee was composed of loose sand, and when the water came against it it showed signs of weakness. A continuous seepage ditch was dug on the land side, and the river slope was sacked. Valuable experience was gained, the ditch especially being of the greatest benefit. With the completion of this work Kempe Levee was thought to be reasonably safe, but the river bank in front commenced to cave rapidly, and on March 26 it threatened to cause a breach by caving in the junction of the new and old levees. A short piece of levee was hastily staked out to cover the threatened point, a force put to work, and a rough piece of embankment completed by April 10. This was an expensive piece of work, as the entire front slope was heavily sacked to prevent injury from rush of water should the front levee cave in. In the meanwhile a very large and dangerous sand boil had developed at the upper end of the old Kempe Levee. It was partially checked by a liberal use of sacks. All the work done was successful, and its total cost for labor was about $4,400.

Gibson Landing Levee (683.5 R.).—The old levee in front showed signs of weakness and a coffer dam of sacks was built to close a dangerous crawfish hole. This cost for labor about $25.

Lake Concordia, including the new Ferriday Levee (693 R.).—As at Kempe, the new Ferriday Levee, to close the crevasse of 1890, was not completed before the river rose over the bank, and it became necessary to build a protection levee to hold out the water until the new bank had been raised to a safe height. The work was successful. With the continued rise of the river the Lake Concordia Levee commenced to show signs of weakness, and considerable work was done in the way of sacking to prevent or remedy wave wash, and earth was wheeled in on the river side to close some of the crawfish holes. By the latter part of April the river having commenced to decline, all danger was supposed to be over, and the protection force was withdrawn. On the night of May 5, a break occurred from some unknown cause within 1,000 feet of the breaks of 1884 and 1890. Fortunately, it was not nearly so disastrous as its predecessors. Owing to the rapidly-falling river and certain topographical features, it only attained a width of 97 feet by a central depth of 12 feet. Circumstances indicated that there was a reasonable prospect of success in an attempt to close it. Work was therefore begun, and the break successfully closed with a sack dike on May 18. Including the cost of closing the break, the work done on this levee cost for labor about $1,800.

Arnauldia Levee (702 R).—The levee being new and exposed to wave wash, had to be sacked on the front at a cost of about $11.

Henderson Levee (712 R).—The sudden rise of the river found this work in a very backward condition. On February 22 the river had risen over the bank at this point, and was only held out by an insignificant ridge of sand hastily thrown up by the contractors. A large portion of the main line of levee was practically untouched, the ground in the vicinity was inundated, and the river rising rapidly. The situation was evidently hopeless, but a few sacks were used to reinforce the small ridge which had been thrown up in front. As anticipated, this was of no avail, and on the night of the 22d the river rose over the bank, and ran through the unclosed gap of 1890.

Deer Park Levee (722 R).—Here, as at several other points, the main line of levee was incomplete, and it was necessary to build a protection levee to restrain the river until the new levee was completed. The quarter boat borrowed from the Atchafalaya work was stationed at this point, and with a force of men and outfit, work was carried on successfully and economically. Two protection levees were built. The one in front about 3,000 feet long to temporarily close the main gap in the old levee, and the other running from a point on the new levee where it was completed to the old levee. The front line held until the new levee was almost completed, and when it was overtopped the second line restrained the water so successfully that a portion of the new Deer Park Levee was not touched by the flood of 1891. The cost of labor on this work was about $1,200.

The only material used on protection work was sacks, of which 44,000 were used, distributed as follows:

Point Pleasant	2,000
Hard Times	1,000
Kempe	16,700
Gibson Landing	1,000
Lake Concordia	17,000
Arnauldia	1,000
Henderson	800
Deer Park	4,500
Total	44,000

SURVEY OF THE MISSISSIPPI RIVER IN THE VICINITY OF NATCHEZ, MISSISSIPPI, AND VIDALIA, LOUISIANA.

The survey was commenced in the early part of February, but operations were soon suspended on account of high water which overflowed the banks. In the latter part of May, when the water had fallen sufficiently, the survey was resumed and is just completed. The field notes have not yet been entirely platted, but will be in a few days when detailed report will be submitted.

GAUGES.

The following Mississipi River Commission gauges in the district have been inspected and corrected during the latter portion of the period covered by this report. St. Joseph, Bayou Sara, Plaquemine, College Point, and Fort Jackson on the Missis-

sippi River; Barbre Landing and Sugar House Chute (the latter recently established) on Old River, and Simmsport and West Melville on the Atchafalaya.

The general condition was found to be good, and although in many instances the permanent or regular gauge staffs had been destroyed by caving banks or other causes, the observers had replaced so closely that no material error was found.

Some improvements in the line of permanency can be made, but a careful instrumental inspection made twice a year, say just before extreme low water and before extreme high water, will render the service accurate and effective within the ordinary and practicable limits.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Lieut. JOHN MILLIS,
Corps of Engineers, U. S. A.

REPORT OF MR. W. G. PRICE, ASSISTANT ENGINEER.

TURNBULL ISLAND, LA., *June 4, 1891.*

SIR: I have the honor to submit the following report on the work of improvement at the junction of Mississippi, Red, and Atchafalaya rivers, covering the period from June 1, 1890, to May 31, 1891.

On June 1, 1890, the condition of the work was as follows: There had been completed dams Nos. 1 and 3 in the Atchafalaya and the sill for the dam to deflect the Red to Upper Old River, and none of these works had been injured during the preceding high water. The plant was laid up at Simmsport and had been put in good condition, except that the repairs to the tug *Comstock* were not complete. The repairs to the *Comstock* were completed June 28.

LOWER OLD RIVER.

The dredge *Pah-Ute* was towed to Lower Old River August 4, and was employed in cutting a channel through the hard clay ridges and deposited the material on one side of the cut. The dredge was kept at work till September 8, when the channel had been cut out so navigation was good. From that date to October 18 the crew were at work rebuilding parts of the dredge and machinery so as to increase its capacity. On October 18 it began cutting through a mass of clay in the channel which had slid in from the bank near Dead Tree. The improvements made to the dredge increased its capacity to 150 cubic yards per hour, and eliminated most of the causes of breakdowns. A considerable time was lost in moving the dredge to the several clay ridges, and from August 28 to September 1, owing to the swift current, the dredge could not be held in position for work. At no time was the river closed to navigation, although from the 8th to the 26th of August steamboats had some trouble in getting through, and for a day or two there was only 2¼ feet of water over the sand bar near Dead Tree, but this bar soon cut out and navigation became good. Six steamboats passed through during the lowest stage, and they were assisted with United States barges, which were used as lighters. The lowest reading on the Red River Landing gauge was 8.8 feet on August 23, 1890, and the lowest on Barbre's gauge was 5.3 feet on August 25, 1890.

The average depth of Lower Old River has increased during the year, and the banks on the bar sides have become higher and steeper, so the water has been better confined to produce scour in the channel.

REPAIRS TO SILL DAMS NOS. 1 AND 3, IN THE ATCHAFALAYA RIVER.

Since the last high water the shore ends above low water of sill No. 3 were injured by the earth sliding down a little on each side of the river below the dam, so as to tear the mat apart and leave cracks from 1 to 4 feet wide, the widest part of the crack or gap being at the downstream edge of the mat. There were two gaps on the right bank and one small one on the left bank. At sill No. 1 the mat above low water, on the left bank, being partly rotted, had been broken away a little at the upstream edge by the swift current. These gaps in the shore mats were repaired in October and January by covering them with small mats well ballasted with rock.

RED RIVER DAM.

The work of constructing crib mats for the dam was begun October 25. The mats were all 3½ feet thick, and were constructed in the same way as the mats had been for the sill. The first course of mats in the dam was 148 feet wide and 410 feet long.

The second course was 132 feet wide and 702 feet long. The third course, which reached only part way across the river, was 104 feet wide and 204 feet long. Each course was composed of mats 68 feet wide, wired together, and was sunk across the current from one side of the river to the other. The mats were ballasted with rock. Before the first course was sunk the sill was covered with a layer of hard blue clay, 2 feet thick, which was dredged at the head of Upper Chute and transported in dump scows. When the work of sinking mats on the dam was finished the crest was nearly on a level with the zero of Barbre's guage. Since then the dam has settled so the lowest point of the crest is 7¼ feet below Barbre's zero. This settling is probably due to the compressing of the mats and clay filling, as a large amount of rock has been used. We have on hand 54,000 square feet of mattress, which was constructed in January and could not be sunk, owing to the lack of rock at the time and high water since. This will be sufficient to complete the third course of mats in the dam. These mats were built out of willows which were cut here for New Orleans Harbor, but they could not be used there on account of the rising river. They have been tied to the bank in the swiftest part of the current near the dam, and have not sunk very low from the sediment collected. Only one mat has had to have the sediment washed out to keep it afloat.

OPENING UPPER OLD RIVER.

On December 4 the dredge *Pah-Ute* began work in Upper Old River at the end of Sugar House Chute. The material dredged was deposited on one side of the cut through a long chute. On December 17 the *Pah-Ute* was moved to the head of Turnbull Island, and the crew were employed in repairing and improving the dredge *Menge*, which had arrived from Vicksburg on December 11, having been borrowed from the third district.

On December 24 the *Pah-Ute* began digging through a shallow place in Sugar House Chute, and continued at work till January 12, when the water became too deep for the dredge to work. The improvements on the *Menge* being nearly completed it was moved to Sugar House Chute on January 27, and excavated 515 cubic yards in 3 hours, but being out of coal, and having no steamboat to move dump scows, the crew were employed in making further improvements. On February 2, having received a little coal, the *Menge* excavated 750 cubic yards, which was cordelled away in a dump scow by hand, and dumped by the crew of the dredge, so the dredge was at work only a small portion of the day. From that time till February 20 the crew continued working on improvements to dredge. The material which was excavated by the *Pah-Ute* and deposited on one side of the cut was a very soft clay mixed with very fine sand. While the dredge was at work considerable of the material slid back into the cut, and it has since nearly all slid back so the channel is very little deeper than before. When we began dredging in this river this year the shoalest place was at the eastern end of Sugar House Chute where the *Pah-Ute* had made a cut through the year before, and part of the material had been carried away in dump scows. When the chute was dry last summer nearly all traces of this cut had disappeared. By sounding through the whole length of Upper Old River with a long pole, I found the material to be all about the same as that which has slid into the cut made by the dredge.

CANAL THROUGH CARR POINT.

The proposed route of this canal starts from Upper Old River at a point 2,000 feet from the foot of Turnbull Island, and enters the Mississippi at a point 6,000 feet from the mouth of Old River, and it is 5,000 feet long. The route is covered with willow trees from 6 inches to 18 inches in diameter. No attempt has been made to determine the kind of material to be excavated except at the Old River end, where the *Pah-Ute* cut in about 200 feet and found hard clay to a depth of 10 feet with coarse sand underneath. The route of the canal has not been cleared of trees except at the Old River end, where it has been cleared 150 feet wide for a distance of 500 feet. This was done in February when the water was so high part of the trees had to be cut by men in pirogues, and they will lie where they fell, and no stumps have been pulled out. On January 20 the *Pah-Ute* began cutting at the Old River end of the canal to show what she could do, the material being deposited on one side of the cut. With the crane down 10 feet the buckets had to cut off the big stumps, and many of the buckets were broken in trying to do so. Then the crane was lowered to 16 feet, and at that depth the buckets could cut off the stumps easily, because they were much smaller, but the stump after being cut off stood up in the bucket and punched the bottom out. These willow trees began to grow when the land was some 20 feet lower than it now is, and the part buried by the filling of the ground must have continued to grow, as they are nearly full size to a depth of 14 feet. The *Pah-Ute*

worked in this place till February 10, a large part of the time being consumed in repairing broken buckets. On February 20 the dredge *Menge* was placed in the cut of the canal made by the *Pah-Ute*, and where of course there were no large stumps. That was done as an experiment to see what the *Menge* could do, and she excavated 4,195 cubic yards in 10 hours and 50 minutes and deposited it on one side of the cut. On account of the trees and stumps it was impossible for the dredges to work, and on February 27 they were towed to the head of Turnbull Island and laid up.

REPAIRS TO DREDGE MENGE.

This dredge arrived from Vicksburg December 11. Before it could be used many improvements, changes, and repairs to machinery had to be made. As originally constructed the dredge could not do good work, and the improvements which had been made, although necessary, were of but little benefit. First the quarters were reconstructed and enlarged so a crew could be comfortably quartered and subsisted on the boat. All the buckets were rebuilt, the shape being changed and the cutters made to work loose on a hinge between stops. The roller track designed by Capt. Dan C. Kingman was entirely rebuilt of new material, the old construction was not in accordance with Captain Kingman's design, and the workmanship was so bad it would not work. All the idlers had to be changed and two additional ones put in. Each pair of idlers work on one shaft, and it is necessary in elevator dredges of this kind to key one of the pair to the shaft, and as the parts of the chains were not quite even in length, there was constant slipping on the idlers, and the strain pulled out sprocket teeth and helped to stretch the chain out of shape. Then both idlers had been run loose on the shaft, and as the shaft did not turn the sand cut the idler hubs and shaft badly. New chimneys were put up, as the old ones were full of holes and ready to fall. The bucket chains having been badly stretched, were adjusted as far as possible, but can never be made perfect again; and there will always be trouble from them till they are worn out and new ones substituted. New sprocket teeth and a sprocket-wheel shaft were put in, and many other improvements made. This dredge has not been used much since it was remodeled, but when tried in the Carr Point Canal it excavated about 4,000 cubic yards in 10 hours. Allowing for break-downs, which all dredges seem to be subject to, with a crew that can handle this form of dredge, I think it can average 2,000 or more cubic yards per day of 10 hours.

MISCELLANEOUS.

All of the plant, except 6 large barges and 5 smaller ones, is in first-class condition, a good deal of repair work having been done. The 6 large barges will be repaired at once, and the 5 smaller ones, which are 8 years old, can be used another year for light work, and will then have to be condemned.

The Red River dam is in good condition, and no further settlement has taken place during the high water. No examination of the dams in the Atchafalaya under water has been made, but as far as is known they are in good condition.

A topographical survey of Carr Point, extending from the Mississippi to Upper Old River was made in July in order to locate the route of the proposed canal.

A resurvey of the Simmsport Reach of the Atchafalaya was made in September.

Measurement of the discharge of the Atchafalaya at Simmsport and of the Mississippi at Red River Landing during the high water were made with current meter number 23, using the launch *Alaska*. Slope observations were also very accurately taken, using instruments of my design, which enabled the party to read the elevation of the water suface very accurately, but no levels have been taken between the slope gauges, so the slope is not known.

Some work has been done towards constructing a telephone line from Turnbull Island to Melville on the Texas Pacific Railroad. The necessary poles have been cut and part of them delivered at Simmsport and much other material purchased, but there being no steamboat available to distribute the poles no work on the line has been done. The work of constructing the line will begin in a few days.

Statement of cost of the different works.

LOWER OLD RIVER.

Dredge *Pah-Ute* excavated 23,492 cubic yards, at 13.7 cents	$3,223.51
Proportion of repairs to dredge during the year	530.27
Services of steamer *Ruby* and proportion of supervision, care, and repair of plant	1,821.28
Total for keeping open a navigable channel	5,575.06

RED RIVER DAM.

589,036 cubic feet of mattress in place, at 2.99 cents	$17,655.59
1,830.7 tons of rock placed on top of dam, at $2.04	3,732.64
6,645 cubic yards of clay under first course, at 15 cents	995.10
898,926 cubic feet of material in place, at 2.49 cents	22,383.33
Proportion of supervision, care, and repair of plant	12,650.91
Proportion of repairs to *Pah-Ute* while digging clay	163.60
898,926 cubic feet in place, all expenses included, at 3.9 cents	35,197.84
Cost of spur levee on left bank	356.32
Cost of rock stored	22,299.17
Cost of mattress on hand	5,872.73
Total cost this year, including material on hand	63,718.06
755,400 cubic feet of mat in place last year, at 2.5 cents	20,122.15
407,720 square feet of shore protection last year, at 5.7 cents	23,324.12
Total cost of dam to May 31, 1891	107,164.33

UPPER OLD RIVER.

Dredge *Pah-Ute* excavated 31,717 cubic yards, at 3.2 cents	1,027.24
Dredge *Menge* excavated 750 cubic yards, at 3.2 cents	23.93
Proportion of repairs to *Pah-Ute* during the year	172.79
Proportion of repairs to *Menge* during the year	1,669.36
Proportion of supervision, care, and repair of plant	593.91
Total expended in cleaning out channel	3,487.23

CANAL THROUGH CARR POINT.

Dredge *Pah-Ute* excavated 5,272 cubic yards, at 8.4 cents	440.92
Dredge *Menge* excavated 4,195 cubic yards, at 5.5 cents	229.76
Cutting out lines and clearing timber from route	238.97
Proportion of repairs to *Pah-Ute* during the year	147.58
Proportion of repairs to *Menge* during the year	1,443.92
Proportion of supervision, care, and repair of plant	513.95
Total expended on the canal	3,015.10

REPAIRS TO DAM IN THE ATCHAFALAYA.

Wages, subsistence, and service of boats	216.04
46 cords of willows, at $1.637	75.30
690 feet lumber, at $15 per M	10.35
100 pounds of nails, at 3 cents	3.00
92 tons of rock, at $2.50	230.00
61 tons of rock, at $1.918	117.00
Proportion of supervision, care, and repair of plant	566.76
Total expended in repair of dams	1,218.45

SURVEYS.

Wages, material, subsistence, and services of boats	658.27
Proportion of supervision, care and repair of plant	371.92
Total expended on surveys	1,030.19

TELEPHONE LINE.

Wages, subsistence, material, and services of boats	1,169.52
Proportion of supervision, care, and repair of plant	660.78
Total expended on telephone line	1,830.30

SUBSISTENCE.

Average cost of a raw ration	$0.345
Average cost of a ration cooked and served with ice	0.515
Cost of care of plant	11,694.33
Cost of repairs to plant	19,792.71
Total expended on this work this year	80,405.59
Value of plant	96,425.23
Value of expendable material on hand	49,175.33

Discharge observations in the Mississippi River at Natchez, Mississippi, March 24 to April 16, 1891.

[B. J. Oliveira, observer from March 24 to April 4; G. Ed. Mott, observer from April 4 to April 16 1891; E. C. Harris, recorder. All computations by G. E. Mott.]

Direction and force of wind.	Date of observation.	Total area.	Mean velocity.	Discharge per second.	Natchez gauge.	Area below zero of Natchez gauge.
		Square feet.	*Feet.*	*Cubic feet.*		
Calm	Mar. 24	156,111.18	9.199	1,436,095.779	46.10	69,101.38
Do	Mar. 25	155,819.34	9.680	1,508,425.248	46.10	68,578.64
Strong; upstream	Mar. 26	155,435.07	8.859	1,377,029.486	46.20	67,928.77
Do	Mar. 27	156,407.92	8.962	1,401,734.867	46.15	69,296.43
Calm	Mar. 28	157,719.16	9.187	1,449,040.903	46.15	70,344.41
Do	Mar. 29	155,879.31	8.787	1,369,759.453	46.18	67,934.42
Light; upstream	Mar. 30	156,614.23	9.762	1,528,869.825	46.15	67,702.70
Brisk; downstream	Mar. 31	158,434.97	9.474	1,501,073.118	46.30	69,213.93
Strong; upstream	Apr. 1	154,682.51	8.953	1,384,982.380	46.35	66,514.63
Strong; downstream	Apr. 2	151,463.33	9.646	1,461,096.365	46.38	62,369.24
Brisk; upstream	Apr. 3	148,178.93	9.154	1,356,549.870	46.38	61,536.46
Calm	Apr. 4	151,082.20	9.183	1,387,472.671	46.40	62,422.93
Brisk; upstream	Apr. 6	152,930.90	8.922	1,365,455.050	46.40	64,100.57
Light; upstream	Apr. 7	152,581.67	9.094	1,387,580.671	46.35	65,530.88
Brisk; upstream	Apr. 8	156,634.19	9.039	1,415,875.764	46.35	68,224.81
Strong; upstream	Apr. 9	148,771.88	9.356	1,391,993.205	46.38	61,728.89
Calm	Apr. 11	151,145.14	8.963	1,354,772.461	46.50	63,986.95
Light; upstream	Apr. 13	145,624.52	9.152	1,332,863.933	46.45	58,947.64
Strong; upstream	Apr. 14	146,992.28	8.983	1,320,537.708	46.38	60,944.11
Calm	Apr. 15	143,392.85	9.230	1,323,600.817	46.35	58,422.31
Light; upstream	Apr. 16	143,446.83	8.457	1,213,252.174	46.30	56,960.31

Discharge observations in the Mississippi River at Red River Landing, Louisiana, March 10 to April 20, 1891.

[G. Ed. Mott, observer from March 10 to April 2, and on April 20; W. G. Price, observer from April 7 to April 16, 1891; R. Y. Briggs, recorder; computations by G. Ed. Mott and R. Y. Briggs.]

Direction and force of wind.	Date of observation.	Total area.	Mean velocity per second.	Discharge per second.	Red River Landing gauge.	Area below zero, Red River Landing gauge.
		Square feet.	*Feet.*	*Cubic feet.*		
Calm	Mar. 10	211,351.80	5.232	1,104,006.553	43.15	50,320.27
Do	Mar. 16	211,682.17	5.333	1,121,616.571	44.53	44,343.35
Do	Mar. 18	211,995.72	5.335	1,122,656.247	44.82	43,147.32
Do	Mar. 20	213,579.40	5.323	1,128,482.979	44.98	44,712.08
Brisk; upstream	Mar. 24	215,487.36	5.393	1,153,858.085	45.03	45,969.71
Strong; downstream	Mar. 27	212,980.82	5.452	1,152,666.526	45.03	44,668.25
Do	Apr. 2	215,466.21	5.424	1,159,852.177	45.17	46,311.82
Light; upstream	Apr. 7	213,281.49	5.449	1,153,300.857	45.21	44,526.31
Calm	Apr. 10	219,078.19	5.248	1,140,914.812	45.37	49,679.52
Do	Apr. 13	221,480.14	5.214	1,145,740.696	45.47	51,050.59
Light; upstream	Apr. 16	220,396.74	5.178	1,132,261.215	45.44	49,653.81
Brisk; upstream	Apr. 20	224,711.42	5.022	1,120,078.854	45.40	51,937.25

Discharge observations in the Atchafalaya River at Simmsport, Louisiana, March 9 to April 27, 1891.

[G. Ed. Mott, observer from March 9 to March 30, and April 17; W. G. Price, observer April 4 to April 15; R. Y. Briggs, observer April 27, 1891. Computations by G. Ed. Mott and E. C. Harris, and C. A. Venus.]

Direction and force of wind.	Date of observation.	Total area.	Mean velocity per second.	Discharge per second.	Simmsport gauge.	Area below zero of Simmsport gauge.
			Feet.	*Cubic feet.*		
Calm	Mar. 9	59,906.50	4.001	239,692.383	40.52	26,818.52
Do.	Mar. 13	59,026.20	4.509	266,155.662	41.60	25,114.90
Do.	Mar. 17	60,448.90	4.587	277,303.343	42.40	25,585.50
Do.	Mar. 19	60,066.70	4.776	286,919.367	42.63	25,281.42
Do.	Mar. 23	63,095.82	4.766	300,756.060	42.81	27,577.19
Light; downstream	Mar. 25	64,328.75	4.761	306,269.243	42.86	28,808.42
Light; upstream	Mar. 28	63,588.07	4.691	298,324.261	42.84	28,152.58
Strong; upstream	Mar. 30	63,217.80	4.783	302,382.327	42.87	27,777.70
Calm	Apr. 4	64,072.32	4.781	306,371.529	43.00	28,474.40
Strong; upstream	Apr. 6	64,114.86	4.796	307,531.740	43.03	28,386.25
Do.	Apr. 9	64,476.60	4.777	308,011.673	43.08	28,657.81
Calm	Apr. 11	63,617.60	5.038	320,545.792	43.20	27,809.00
Light; upstream	Apr. 15	64,303.05	4.843	311,443.216	43.28	28,437.96
Do.	Apr. 17	63,612.02	4.799	305,281.846	43.29	27,713.83
Light; downstream	Apr. 27	63,922.15	4.877	311,791.003	43.31	28,238.33

Very respectfully,

W. G. PRICE,
U. S. Assistant Engineer.

Lieut. JOHN MILLIS,
Corps of Engineers, U. S. A.

REPORT OF MR. W. J. HARDEE, ASSISTANT ENGINEER.

NEW ORLEANS, LA., *June 12, 1891.*

SIR: I have the honor to submit the following report upon the work of which I have had immediate charge during the year ending May 31, 1890:

LEVEES.

RIGHT BANK BELOW RED RIVER—CONSTRUCTION.

On June 1, 1890, there were no funds for, or property belonging to, levee work in this district. During the month of October, 1890, the Mississippi River Commission allotted $112,500 for levee purposes. During the early part of December the same year that amount was increased to $130,500, of which 5 per cent. was reserved for protection work and 10 per cent. of the balance for contingencies.

New lines of levee at Nina, Highland, Barroza, and Evergreen were recommended for construction to provide for breaches threatened in the existing lines by caving banks. The Louisiana State Board of Engineers had made preliminary surveys and approximate estimates for new levees at each of the named places. It was deemed advisable to revise these locations, which was done between December 8 and 10, 1890, by the United States after it had assumed charge.

Nina Levee.—This levee by the line of December 8, 1890, was 6,115 feet long and required 76,500 cubic yards for its construction. The contract was let to S. L. James, jr.

On November 20, 1890, the contractor promptly moved a force to the levee. The owners of the Nina plantation and the residents of the village at Cook Landing, through which the line was located, opposed the construction of the levee on the line selected. Pending an investigation of the opposition the contractor was furnished construction notes from station 40 to station 62 plus 15, a distance of 2,215 feet.

On January 28, 1891, you visited the locality and selected a location which put all of Cook Landing village and the Nina plantation sugar mill and annexes on the river side of the line. This new section of the line was 44 feet longer than the original one, and required 18,826 cubic yards more for its construction. The new location was even more objectionable to the owners of the Nina plantation than the original line. They endeavored to secure an injunction to restrain the construction of that

part of the levee, but owing to their insolvent condition their efforts were unsuccessful. The people of Cook Landing village interposed no objection to the new line.

The contractor was furnished with only 3,344 feet of construction notes on the new line, as it was decided to allow a space of 600 feet to remain open to afford easy means for the removal of the Nina plantation buildings from the present position to a point in the rear of the levee. A supplemental contract was made with the contractor, S. L. James, jr., for the construction of the 600 feet left open, at a date not later than February 1, 1892.

Owing to the late date at which notes for the revised location were furnished the contractor was unable to complete his contract within the stipulated time, and an extension of 180 days was given him in which to finish the levee.

On May 31, 1891, there were 5,359 feet of levee completed and accepted, embracing 72,443 cubic yards, which was all the levee for which notes had been furnished, with the exception of 200 feet. That 200 feet is a dike across a deep bayou. On May 3, 1891, work was well advanced on the dike, and there remained the handling of about 5,000 cubic yards to complete it.

The average height of Nina Levee is 9 feet. It is built with a 6-foot crown and side slopes of 3 to 1.

The largest force employed on 1 day on this levee was 139 men, 46 mules, 100 wheelbarrows, and 21 scrapers.

Highland Levee.—This line, as projected by the Louisiana State board of engineers, was 10,900 feet long and estimated to contain 330,000 cubic yards. The revised location made the levee 10,121 feet long and required 243,000 cubic yards for its construction.

Messrs. Andrews & Ogden were awarded the contract for this work on November 20, 1890, and immediately moved a small force to the locality. The line was re-run subsequent to the award of the contract.

The allotment of $130,500 was found to be about $28,000 short of what was necessary to build the four levees recommended. The shortage was applied to this levee. The available money allowed the construction of 5,570 feet of levee, for which length of line construction notes were issued.

Owing to the late date at which the work was contracted for and the bad weather experienced, added to other unfavorable local conditions, the contractors were unable to complete the work within the stipulated time. In consideration of these facts an extension of 90 days, or until June 1, was granted them in which to do the remaining work. During the months of March, April, and May the river was at such an elevation as to create a very free transpiration of water through and under the existing levee. This saturated the ground and rendered progress very slow. By June 1, 1891, the contractors had constructed 5,170 feet of levee, containing 126,956 cubic yards. This work was measured and inspected. It was found satisfactory, and accepted. It was paid for in the form of a final estimate, and the contract declared terminated.

The average height of Highland Levee is 14 feet. It is built with an 8-foot crown and side slopes of 3 to 1.

The largest force employed on 1 day was 100 men, 130 mules, 29 wheelbarrows, and 47 scrapers.

Barroza Levee.—As originally staked this levee was 4,105 feet long and estimated to require 200,000 cubic yards for its construction. The alignment was changed to 4,145 feet and the yardage to 164,861. The contract was let to Andrews & Ogden on November 20, 1890. The contractors promptly moved a large force to the locality. The force was present and awaiting the revision of the line, that it could secure construction notes and start to work. The force was almost daily increased until it reached the proportions of 210 men, 194 mules, 74 wheelbarrows, and 77 scrapers, which was the largest number employed on one day.

The levee averages 17¼ feet high. It is built with an 8-foot crown, a river-side slope of 3 to 1 and a land-side slope of 4 to 1.

The ground on which the base of the levee is situated is low. To provide against the accumulation of rain and seep water the contractors erected a drainage pump and spent a large amount of money in canal ditching. The pump and ditches rendered valuable service, but in spite of the large force employed and the increasing efforts of the contractors it was impracticable to complete the levee within the required time, owing principally to the loss of time occasioned by bad weather experienced during November, December, and January. The time for completion was therefore extended to June 1, 1891.

On May 30, 1891, the levee was reported completed. It was inspected and measured, and being found satisfactory, was received from the contractors and paid for.

Evergreen Levee.—This line as originally staked was 3,380 feet long and estimated to contain 70,000 cubic yards. The line was changed and made 3,400 feet long. It was found that the estimate of 70,000 cubic yards was based on a grade 3 feet lower than that recently adopted throughout the district. The grade was raised 3 feet to cor-

respond to the new grade, and thereby increased the contents to 93,655 cubic yards. The average height of this levee is now 14¼ feet. The crown is 8 feet wide and the side slopes 3 to 1.

The contract was awarded to Flynn & De Garis on November 20, 1890. Shortly after they moved a fair-sized force to the work, which amounted when largest to 44 men, 56 mules, 11 wheelbarrows, and 26 scrapers.

Owing to lack of natural drainage, the rains that fell in November, December, and January, and the great amount of seep water encountered during the succeeding months, accumulated on or about the space from which earth had to be obtained, and proved an obstacle to the progress of the work. The increased grade further limited the space between the old and new levees, already narrow to furnish so large an amount of construction material. These several conditions prevented the completion of the contract by the stipulated time for completion, and the date was extended to July 31, 1891.

On May 31, 1891, the work was in the following condition:

Commenced	feet	3,400
Completed and accepted	do	1,100
To complete	do	2,300
In place	cubic yards	60,384
Yet to be handled	do	33,271

One assistant engineer in general charge, one traveling inspector, and one local inspector stationed at each levee was the force employed directly by the United States for the necessary care and inspection of the levees while building.

REPAIRS.

During the month of February, 1891, an inspection was made of the levees built by the United States subsequent to the year 1881 between Barbre, Louisiana, and Point Coupee Crevasse, Louisiana, a distance of about 60 miles. Some of these levees were found in bad condition and requiring repairs to reëstablish the crown and slopes, which had become partially destroyed by rain and wave washing.

The levees requiring the most immediate work were in the vicinity of Red River Landing, Louisiana. A master laborer was sent to the locality, and executed the following work:

Levee repaired	linear feet	5,480
Ditch cut to destroy crayfish holes	do	815
Stumps removed from the base of the levee		29

For that service all working outfit was borrowed from the Red and Atchafalaya River plant, and returned to that work when operations were concluded.

PROTECTION WORK.

In the immediate vicinity of Red River Landing, Louisiana, the river never reached a dangerous elevation, and scarcely any protection work was necessary.

From a point about opposite Baton Rouge, La., to the lower limit of the levee, the river reached a dangerous stage about March 1, 1891.

The same barge outfit with which operations were carried on for protection work on "Levees Left Bank" rendered service at Evergreen Levee, where 2,010 feet of revetment was constructed to correct wave washing of the front slope of the old or front levee at that place.

This work expended 12,300 feet B. M. of lumber, 110 pounds of nails, and 25 sacks.

When Baton Rouge was reached the barge was moored there, and a trip was made on the U. S. steamer *Florence* as far as Barbres, Louisiana. In that distance the line of levees was generally inspected, but particularly those built by the United States. They were all found in fair condition and requiring no work.

At Nina plantation, where the United States was constructing a new line, the front slope of the old levee began washing badly, and 625 sacks were expended to prevent further loss of levee.

At Highland, La., where the United States was constructing a new line, there were two roadways which had been worn in the old levee. Both were filled at a small cost.

On April 2, 1891 the barge and party left Baton Rouge to return to New Orleans. On the way down the line of general levees was inspected and found in good condition. During the latter part of February and early part of March the local authorities did a large amount of repair work to strengthen probable weak places.

During March, 1891, the Mississippi River Commission allotted $43,750 for protection work in this district. At the time the money became available the levees were in good condition and required but little work.

During the flood period a drought prevailed, which was of material benefit to the levees. Had there prevailed the rains usually experienced at that time of the year, it is safe to assume that a very greatly increased amount of work would have been necessary to properly secure the levees. As it was, so little work was necessary that only a small percentage of the funds allotted for protection work was expended.

On April 8, 9, and 10 an inspection was made of the general line of levees between New Orleans, La., and Fort Jackson, La. The water was found to be several feet below the tops of the levees. They were all in good condition and required no work, as they were all secure against the existing height of water.

LEFT BANK BELOW RED RIVER.—CONSTRUCTION.

On June 1, 1890, there were no funds for, or property belonging to, levee work in this district. During the month of October, 1890, the Mississippi River Commission allotted $67,500 for levee purposes. It was contemplated that the United States would survey and contract for work to the extent of that allotment.

The Pontchartrain levee board, a local organization created by the Louisiana State legislature, had contracted for and was constructing eighteen levees between New Orleans and Baton Rouge. That board became involved in litigation over the collection of a produce tax it had levied. Finding itself deprived of its revenue and unable to successfully complete its contracts for levees then building, it applied to the honorable Secretary of War for relief, resulting in a reconvention of the Board of United States District Officers and the application of the allotted funds to the completion of the existing contracts, the United States to pay for work done on those contracts subsequent to November 20, 1890, only.

The work covered by the contracts in question was of the most important as well as of the most immediately necessary in the district.

During the early part of December, 1890, the allotment of $67,500 was increased to $94,500, of which 5 per cent. was reserved for protection work and 10 per cent. of the balance for contingencies. It was found that the amount available for actual construction expenditure lacked about $5,000 of being sufficient to cover all the work to be done on the Pontchartrain levee board contracts. The balance of work on the south port to Camp Parapet Levee, Jefferson Parish, La., amounted to about that figure. The United States notified the Pontchartrain levee board of its inability to proceed with that levee, but assumed direction of the other seventeen works, all of which were carried to a successful completion without incident worthy of special mention.

Copies of prescribed measurements for construction of respective levees were secured at the office of the Louisiana State Board of Engineers.

All work done prior to November 20, 1890, the date at which the United States assumed charge of the levees, was carefully inspected and measured and found to have been executed in a satisfactory manner and in strict compliance with the contract in each case.

During the period of construction the largest aggregate force employed on one day was 647 men, 510 mules, 197 scrapers, and 304 wheelbarrows.

The following subordinate force was employed directly by the United States for the necessary inspection and care of the several levees: One inspector, $3\frac{28}{30}$ months, at $90 per month; one rodman, $1\frac{28}{30}$ months, at $50 per month; one rodman, $2\frac{17}{30}$ months, at $60 per month; one watchman, $1\frac{11}{30}$ months, at $75 per month; one watchman $\frac{18}{30}$ months, at $50 per month.

PROTECTION.

During the month of February, 1891, the river rose steadily, and on March 1 its elevation was several feet above the danger line throughout the district.

The strain put upon the line of embankment by the high stage of the river developed many weak places. The greatest trouble experienced and requiring most work for correction was the wave-washing of the front slope of the levees. The action of the water on the front slope created an erosion which, unless stopped, would eventually broach the embankment.

On March 10, 1891, a barge fitted with sleeping and eating apartments and having on board 15 laborers and 1 cook, together with lumber, sacks, and working tools, left New Orleans, towed by the United States tug *Parker*, for protection service north of New Orleans. The barge and the major part of the outfit used on it was borrowed from the New Orleans Harbor work and returned to that work when the expedition was disbanded. Some few tools were purchased for this special service. A small amount of the lumber used was purchased at New Orleans and Plaquemine, La. The greater portion was taken from an amount purchased by Capt. Dan. C. Kingman during the flood of 1890, and stored by him at Plaquemine, La., at which place it was transferred to the barge.

The barge and party went as high as Baton Rouge, La.; returning, arrived at New Orleans on April 6, 1891. During that time the general line of embankment was inspected, particularly the levees just completed by the United States.

From commencement to date of discharge the following boats rendered service as stated in connection with protection work:

	Days.
United States tug *Parker*	4
United States steamer *Florence*	5
United States tug *Tilda*	8
Tug *Wm. Williams*	½

The following statement shows where services were rendered and the amount of work done, together with material expended at each place:

Levee.	Below Cairo.	Length of levees worked on.	Lumber expended.	Sacks expended.	Nails expended.
	Miles.	*Feet.*	*Feet.*	*Number.*	*Pounds.*
St. Gabriel	862.0	60	700	240	18
Southwood*	875.5	45	2,400	330	20
Ashland*	878.0	2,200	5,400	100	60
Dicharry*	882.0	800	2,800	150	32
Total		3,105	11,300	820	130

* Denotes United States levees.

In addition to the work embraced in the foregoing table, the old or front levees were cut at Southwood (875.5 L), Union (893.5 L), and Terre Haute to Hope (919.5 L) United States levees, to put the river water against the new levee at each place.

During the month of March, 1891, the Mississippi River Commission allotted $23,688 for protection of levees in this district.

To fully secure the levees immediate work was required at numerous places at the same time. As the working capacity of the barge party was limited, you made an arrangement with Mr. A. M. Cooke, assistant general manager of the Louisville, New Orleans and Texas Railroad, by virtue of which the following work was done:

Longwood Levee (847.5 L), 662 linear feet of revetment was erected, at a cost of	$99.40
Davenport Levee (838 L), 200 linear feet of revetment was erected, at a cost of	158.40
Melancon Levee (888 L), 700 linear feet of revetment was erected, at a cost of	136.00

On April 9, 10, and 11 inspection was made of the levees below New Orleans, on the left bank, as far as Fort St. Philip. They were found to be generally in good condition, the flood elevation several feet below their grades, and no work necessary, as all was perfectly secure.

Respectfully submitted.

W. J. Hardee,
Assistant Engineer.

Lieut. John Millis,
Corps of Engineers, U. S. A.

REPORT OF MR. WILLIAM GARVIN, ASSISTANT ENGINEER.

New Orleans, La., *June 1, 1891.*

Sir: I have the honor to submit the following report upon the work of which I have had immediate charge during the year ending May 31, 1891:

WORKS OF IMPROVEMENT IN NEW ORLEANS HARBOR, LOUISIANA.

At date of last report, May 31, 1890, the condition of the work was as follows:

The plant was in laying-up quarters at Exposition Wharf and repair work was being done on tug *Tilda*, which had been partially destroyed by fire on the night o May 8, the house, deck, top timbers, furniture, and tools being entirely destroyed The repairs were completed and the tug ready for duty July 23.

On August 2 the *Tilda*, in company with the steamer *General Newton*, left laying u quarters with a tow of nine barges and quarter boat to cut willow brush for work in Carrollton Bend. They returned September 19 with eight loaded barges, with 3,396.8 cords brush and 174.30 cords poles, at a total cost of $7,400.62 or $2.072 pe

cord. The length of time occupied in cutting willows is due to a scarcity of labor, the work being dependent to a great extent on local and colored labor.

During the absence of plant cutting willows, barge No. 3 was repaired at Exposition Wharf, and new crib and mattress ways built. It being decided that a mattress built in sections would be more convenient to handle and place in position between barges, the ways were constructed on an old coal barge; they are suitable for building a mattress 100 feet in length by any required width.

Construction of mattress for Spur No. 4 was commenced September 24 and completed October 6. It was not sunk until November 7; this was owing to the barges used for sinking being loaded with willow brush. The frames of this mattress were of the same build and material as those used in the mattress in the third district front. The manner of placing the willows was somewhat different, they all being placed parallel to each other at right angles to frames. The bottom layer of willows were all securely nailed to frames. This mattress was built in four sections, three 100 by 130 feet and one 55 by 130 feet. The different sections were then placed in position along side of lowering barges and securely fastened together, each frame being fished and then fastened with No. 10 galvanized wire. The head or upstream frames were built of 3-inch by 6-inch lumber and strengthened at each toggle pin by three lines of iron rods, one running straight and one on each side of pin diagonally across mattress, crossing frames and securely fastened with wire to each frame. The frames being at right angles to bank or slope, poles are placed at proper distances apart, according to slope, to keep rock from shifting or rolling out in stream. The manner of attaching lowering and toggle lines, loading, and sinking were the same as in the third district front.

The dimensions of the mattress were 355 by 130 by 1.75 feet thick, and the cost and material were—

607.9 cords brush, at $2.07	$1,258.35
13,472 feet, B. M., 2 by 4 inch lumber, at $10.90 per M	146.84
2,749 feet, B. M., 3 by 6 inch lumber, at $10.90 per M	29.96
298.67 tons rock, at $2	597.34
991 pounds No. 10 galvanized wire, at 4 cents	39.64
1,200 pounds 9-inch steel-wire nails, at 3½ cents	42.00
2,700 pounds 6-inch steel-wire nails, at 3 cents	81.00
300 pounds 3½-inch steel-wire nails, at 3.30 cents	9.90
3,787 pounds rod and mattress chain, at 3½ cents	132.54
86 bolts ⅝-inch iron, at 5 cents each	4.30
131 fishplates, at 7 cents each	9.17
1,200 rations, at 30 cents	360.00
Labor, including tug, superintendence, etc	1,995.91
Total	4,704.95

Number of square feet in mattress	46,150
Pounds of rock per square foot to sink	12.94
Cost per square foot in place	$0.1019

Construction of cribs for Spur No. 4 was commenced September 22 and finished October 13. The last crib was sunk on Spur November 13.

The dimensions of the cribs built and sunk on this spur were—

	Feet.
Crib No. 1	120×56×6
Crib No. 2	152×48×6
Crib No. 3	170×40×6
Crib No. 4	200×32×6
Crib No. 5	274×24×6
Crib No. 6	310×16×6

Cost and material were—

1,386.8 cords brush, at $2.07	$2,870.67
68 cords poles, at $2.07	140.76
580.45 tons rock, at $2	1,160.90
37,380 feet, B. M., 3 by 6 inch lumber, at $10.90 per M	407.44
2,090 pounds No. 10 galvanized wire, at 4 cents	83.60
456 pounds iron rods, at 3½ cents	15.96
1,950 pounds 9-inch steel-wire nails, at 3½ cents	68.25
200 pounds 6-inch steel-wire nails, at 3 cents	6.00
1,500 rations, at 30 cents	450.00
Labor, including tug, superintendence, etc	3,100.16
Total	8,303.74

Number of cubic feet of crib work in spur	2,325.12
Pounds of rock per cubic foot to sink	4.99
Cost per cubic foot in place	$0.0357
The total cost of spur was	$13,008.69

Construction of mattress for Spur No. 3 was commenced October 6 and finished October 18. It was sunk November 21. The style of mattress was the same as on Spur No. 4, and its dimensions were 415 by 140 by 1.75 feet thick.

The cost and material were:

618 cords brush, at $2.07	$1,279.26
3,126 feet, B. M., 3 by 6 inch lumber, at $10.90	34.07
18,182 feet, B. M., 2 by 4 inch lumber, at $10.90	198.18
372.32 tons rock, at $2	744.64
1,166 pounds No. 10 galvanized wire, at 4 cents	46.64
1,300 pounds 9-inch steel-wire nails, at 3½ cents	45.50
2,350 pounds 6-inch steel-wire nails, at 3 cents	70.50
175 pounds 3½-inch steel-wire nails, at 3.30 cents	5.77
4,335.21 pounds rods and mattress chain, at 3½ cents	151.73
98 fish plates, at 7 cents each	6.86
2,000 rations, at 30 cents	600.00
Labor, including tug, superintendence, etc	2,600.76
Total	5,783.91

Number of square feet in mattress	58,100
Pounds of rock per square foot to sink	12.81
Cost per square foot in place	$0.0995

Construction of cribs for Spur No. 3 was commenced October 18 and finished December 20. The last crib was sunk December 22. The dimensions of the cribs built and sunk on this spur were:

	Feet.
Crib No. 1	50 × 64 × 6
Crib No. 2	154 × 56 × 6
Crib No. 3	220 × 48 × 6
Crib No. 4	245 × 40 × 6
Crib No. 5	270 × 32 × 6
Crib No. 6	345 × 24 × 6
Crib No. 7	400 × 16 × 6

The cost and material were:

784.1 cords brush, at $2.07	$1,623.08
826.8 cords brush, at $2.25	1,860.30
106.3 cords poles, at $2.07	220.04
83.9 cords poles, at $3.25	272.67
989 tons rock, at $2	1,978.00
50,630 feet B. M., 3 by 6 inch lumber, at $10.90 per M	551.86
2,843 pounds No. 10 galvanized wire, at 4 cents	113.72
268 pounds rods, at 3½ cents	9.38
18 bolts ⅝-inch iron, at 5 cents each	.90
3,600 pounds 9-inch steel-wire nails, at 3½ cents	126.00
300 pounds 6-inch steel-wire nails, at 3 cents	9.00
2,200 rations, at 30 cents	660.00
Labor, including tug, superintendence, etc	4,423.19
Total	11,848.14

Number of cubic feet of crib work	330,072
Pounds of rock per cubic foot to sink	5.44
Cost per cubic foot in place	$0.0358
The total cost of spur was	$17,632.05

Construction of mattress for Spur No. 5 was commenced December 22, 1890, and completed and sunk January 13, 1891. The dimensions of the mattress were 400 by 120 by 1.75 feet thick, and the cost and material were:

356.18 cords brush, at $2.23	$794.28
70.58 cords brush, at $2.25	158.80
3,252 feet, B. M., 3 by 6 inch lumber, at $10.90 per M	35.44
16,560 feet, B. M., 2 by 4 inch lumber, at $10.90 per M	180.50
294 tons rock, at $2	588.00

1,027 pounds No. 10 galvanized wire, at 4 cents	$41.08
1,000 pounds 9-inch steel-wire nails, at 3½ cents	35.00
2,800 pounds 6-inch steel-wire nails, at 3 cents	84.00
400 pounds 3½-inch steel-wire nails, at 3.30 cents	13.20
1,082 pounds rods and mattress chain, at 3½ cents	37.87
12 bolts ⅝-inch iron, at 5 cents each	.60
54 fish plates, at 7 cents each	3.78
1,400 rations, at 30 cents	420.00
Labor, including tug, superintendence, etc	2,159.40
Total	4,551.95

Number of square feet in mattress	48,000
Pounds of rock per square foot to sink	12.25
Cost per square foot in place	$0.0948

The dimensions of the cribs built and sunk on this spur were:

	Feet.
Crib No. 1	96 × 40 × 6
Crib No. 2	230 × 32 × 6
Crib No. 3	308 × 24 × 6
Crib No. 4	370 × 16 × 6

Crib No. 1 was built and sunk in two sections, one section 40 by 40 by 6 feet, and one 56 by 40 by 6 feet. There is a space of 32 feet between sections when sunk in position.

The construction of cribs was commenced December 20, 1890, and completed and sunk January 22, 1891.

The cost and material were:

948.09 cords brush, at $2.25	$2,133.20
56.94 cords poles, at $3.25	185.05
530.29 tons rock, at $2	1,060.58
24,328 feet, B. M., 3 by 6 inch lumber, at $10.90 per M	264.19
1,729 pounds No. 10 galvanized wire, at 4 cents	69.16
429 pounds iron rods, at 3½ cents	15.01
1,700 pounds 9-inch steel-wire nails, at 3½ cents	59.50
100 pounds 6-inch steel-wire nails, at 3 cents	3.00
700 rations, at 30 cents	210.00
Labor, including tug, superintendence, etc	2,350.15
Total	6,349.84

Number of cubic feet of crib work	14,072
Pounds of rock per cubic foot to sink	7.21
Cost per cubic foot in place	$0.0431
The total cost of spur was	$10,901.79

The total cost and material for the three spur dikes built in Carrollton Bend were:

3,396.8 cords brush, at $2.07	$7,031.37
1,845.47 cords brush, at $2.25	4,152.30
356.18 cords brush, at $2.23	794.28
174.3 cords poles, at $2.07	360.80
140.84 cords poles, at $3.25	457.73
3,064 tons rock, at $2	6,129.46
48,214 feet, B. M., 2 by 4 inch lumber, at $10.90 per M	525.53
121,375 feet, B. M., 3 by 6 inch lumber, at $10.90 per M	1,322.98
9,846 pounds No. 10 galvanized wire, at 4 cents	393.84
10,750 pounds 9-inch steel-wire nails, at 3½ cents	376.25
8,450 pounds 6-inch steel-wire nails, at 3 cents	253.50
875 pounds 3½-inch steel-wire nails, at 3.30 cents	28.87
10,357.21 pounds rods and mattress chain, at 3½ cents	362.50
116 bolts, ⅝-inch iron, at 5 cents each	5.80
283 fish plates, at 7 cents each	19.81
9,000 rations, at 30 cents	2,700.00
Labor, including tug, superintendence, etc	16,627.57
Total	41,542.59

Average cost of crib work per cubic foot	0.0359
Average cost of mattress per square foot	0.0987

The cost of the mattresses was in excess of those built for the third district work. This is due to the increased cost of willow brush and poles and a greater quantity of brush used per square foot of mattress. Owing to the swifter current along this bank the mattresses were built considerably stronger than any used heretofore, consequently a greater amount of rods, mattress chain, and wire were used. During the sinking of the cribs on Spur No. 5 there was a considerable rise in the river, accompanied by heavy drift. This delayed the work and increased the expense.

Material on hand to be used for spur-dike construction.

45 cords willow brush, at $2.25	$101.25
334.37 cords willow poles, at $3.25	1,086.70
5,000 feet, B. M., 2 by 4 inch lumber, at $10.90 per M	54.50
3,591.76 tons rock, at $2	7,183.52
6,072.37 pounds ½-inch rods, at 3½ cents	212.53
4,555.51 pounds ⅝-inch rods, at 3½ cents	159.44
3,006 pounds mattress chain, at 3½ cents	105.21
Total	8,903.15

During the construction of Spur No. 3 the tug *Tilda* had her propeller knocked off and the tug *Alert* was employed to do the work. The *Tilda* was taken to laying-up quarters at Exposition Wharf, where a temporary dock was constructed of an old coal barge and the tug docked and the hull rebuilt. This repair was expensive, as it was necessary to put in new stem and stern post, forefoot and deadwood in bow. Nearly all the timbers top and bottom were renewed, in fact the only old timber remaining in the hull is the keel, bottom timbers under bed plate of engine, and 6 or 8 of the plank along the keel. These were perfectly sound and not necessary to renew. Some changes were made in the cabin, the kitchen being enlarged and extended back over boiler to admit of a pump in the forward end. Changes were made in the after cabin to admit of a closet in after end of boat. The repair to hull and cabin cost for material $1,073.83, and for labor $2,013.75. The machinery was thoroughly overhauled and repaired. It was fitted with new brasses, crank-pin, propeller, stern bearing, breeching, copper pipe from throttle valve to steam chest, and various other minor improvements and repairs. The cost of material for the repair of machinery was $598.53, and the cost of labor was $270.

The tug *Tilda* has been fitted with a No. 10 Cameron fire and wrecking pump. It has a capacity of 500 gallons per minute when being used for wrecking purposes. The cost of pump in place, including all pipe and hose connections, was $794.26, making a total cost for repairs and improvements of $4,750.37.

After the completion of Spur No. 5 the willow brush and poles on hand were unloaded on the bank and the entire plant moved to Exposition Wharf. Repairs were then commenced on Barges Nos. 1, 2, and 3. They were turned bottom up and new rake planking put on, the bottoms calked and tarred, the decks calked, pitched, and tarred, the sides calked and painted, the insides thoroughly cleaned and whitewashed. The cost of material for repair of these barges was $454.42, and the cost of labor $1,901.85, making a total of $2,356.27 or $785.42¼ each. The old warehouse barge, being rotten and worthless, was beached at Exposition Wharf, and will be used for storing worthless and such material as is not required during spur-dike construction.

Barge No. 6 has been converted into a warehouse. Some minor repairs were done to hull, and a house built 110 by 26 feet. The roof was made of inch plank covered with P. & B. roofing paper. The cost of material was $273.69, and the cost of labor was $454.75, making a total of $728.44.

Barges Nos. 4 and 5 have been cleaned, whitewashed and painted, and some repairs done to sides and decks. Nos. 9, 10, and 11 have been cleaned, whitewashed and painted. They have also been calked and pitched. This, with cleaning, drying, and storing manilla lines, cleaning and painting wire lines, loading and unloading lumber, poles, and different material, moving fleet to laying-up quarters and caring for same, has cost approximately $1,625.25, including labor and material.

Steam launch No. 1, received from Warrenton observation party in June, 1889, has been condemned and beached at Exposition Wharf. Launch No. 5, received from St. Louis May 16, 1891, required some repairs to stern-bearing. She is otherwise in good condition.

The quarter boat is on ways having the hull rebuilt. The cost to date has been for material, $544, and for labor, $1,405.25.

Surveys were made in the Gouldsboro, Carrollton, and third district bends by Assistant Engineer W. J. Hardee. The Carrollton survey extended a distance of 6,875 feet of shore line. The soundings were run out until the channel was fully

measured and the incline of the opposite bank encountered, which was nowhere less than 550 feet, and as much as 750 feet from edge of water. Six thousand three hundred and ninety-eight soundings were taken, an average of 1 sounding to about every 25 feet square. This survey cost $330.

Third district survey extended over 5,800 feet of shore line. The soundings were run out from 600 to 1,000 feet from edge of water.

PROTECTION OF LEVEES.

The machinery of the United States tug *Parker* was repaired at a cost for brasses and machinist of $200.92, and for labor, $45.90; total, $246.82, charged to levees. Barge No. 8 was fitted with temporary house covered with tarpaulins, to be used as quarter boat by Assistant Engineer Hardee, on protection of levees. The cost for material was $16, and the cost for labor was $56.25, making a total of $72.25 charged to protection of levees. The United States steamboat *Thos. B. Florence* was repaired at a cost of $59.65 for labor and $35.10 for material.

SURVEYS, GAUGES, AND OBSERVATIONS, AMES CREVASSE.

The break occurred March 16, about 9 or 9:30 p. m. I learned from residents at the company canal that the break was caused by the rice flume, an iron pipe that was put in the levee about October, 1890. The water did not make its way along the pipe, but about 3 feet below the crown on the river side and its outlet, about 5 feet above the base, on the land side. This was due to the earth not being properly packed in the cut made through the levee.

I measured the crevasse on March 18, and found the width 164 feet, the upper edge of break being 434 feet below center line of Spur No. 1, Greenville Bend, and the lower edge 382 feet above Spur No. 2. The greater caving has taken place on the lower side; the lower side is now 767 feet below center line of Spur No. 2, making a total increase of 352 feet—a total of 1,501 feet since first measurement.

Daily measurements and gauge readings were taken at points above and below the crevasse, and one gauge established on opposite shore to crevasse.

A tabular statement of daily measurements and gauge readings is given herewith:

Observations at Ames Crevasse.

Date.	River gauge at company canal.	Backwater gauge in company canal.	River gauge, 376 feet above center line of Spur No. 1.	Backwater gauge, 376 feet above Spur No. 1.	River gauge, 345 feet below center line of Spur No. 2.	Backwater gauge, 345 feet below center line of Spur No. 2.	River gauge, 1,840 feet below center line of Spur No. 2.	Gauge opposite bank of river from crevasse.	Carrollton gauge.	Total width of crevasse.	Increase on upper side.	Increase on lower side.
1891.												
Mar. 18	......	......	15.72	7.64	15.51	7.69	15.27	......	15.80	164.0	......	......
19	15.34	......	15.42	7.94	15.21	7.89	14.92	14.94	15.65	234.0	21.0	49.0
20	15.24	......	15.32	8.28	15.11	8.19	14.87	14.89	15.55	365.0	19.0	112.0
21	15.09	......	15.22	8.64	15.01	8.69	14.77	14.79	15.40	466.0	40.0	61.0
22	15.04	......	15.12	8.84	14.81	8.79	14.57	14.54	15.30	510.0	13.0	31.0
23	14.94	......	15.02	9.04	14.81	8.89	14.57	14.54	15.30	535.0	3.0	22.0
24	14.92	7.16	14.97	9.14	14.81	8.99	14.51	14.64	15.20	563.0	3.0	25.0
25	15.04	7.31	15.12	9.24	15.01	9.19	14.67	14.64	15.30	617.0	32.0	22.0
26	15.04	7.46	15.02	9.34	14.91	9.29	14.62	14.59	15.30	665.0	39.0	9.0
27	14.84	7.46	15.02	9.34	14.91	9.29	14.52	14.59	15.10	678.0	8.0	5.0
28	14.74	7.46	14.82	9.34	14.71	9.29	14.47	14.29	15.00	687.0	4.0	5.0
29	14.84	7.41	14.92	9.44	14.61	9.29	14.42	14.39	15.00	693.0	0.0	6.0
30	14.84	7.56	14.90	9.54	14.71	9.39	14.47	14.39	15.00	713.0	3.0	17.0
31	14.94	7.66	15.12	9.54	14.96	9.39	14.57	......	15.20	732.0	8.0	11.0
Apr. 1	14.94	7.71	......	9.64	14.91	9.39	14.57	14.59	15.15	749.0	8.0	9.0
2	14.84	7.76	14.92	9.64	14.81	9.39	14.47	14.49	15.00	848.0	29.0	70.0
3	14.79	7.81	14.82	9.69	14.81	9.39	14.37	14.39	15.05	891.0	0.0	43.0
4	14.74	7.81	14.82	9.69	14.61	9.44	14.22	14.29	14.75	930.0	0.0	39.0
5	14.64	7.86	14.82	9.64	14.51	9.29	14.17	14.29	14.90	964.0	0.0	34.0
6	14.44	7.86	14.62	9.69	14.31	9.34	14.12	14.04	14.80	983.0	0.0	19.0
7	14.34	7.86	14.47	9.74	14.31	9.39	14.07	13.99	14.65	1,006.0	0.0	23.0
8	14.54	7.89	14.62	9.74	14.41	9.39	14.17	14.09	14.75	1,017.0	0.0	11 0
9	14.69	7.96	14.77	9.94	14.41	9.49	14.27	14.24	14.80	1,029.0	0.0	12.0
10	14.74	8.01	14.82	9.94	14.51	9.49	14.37	14.34	......	1,035.0	0.0	6.0

Observations at Ames Crevasse—Continued.

Date.	River gauge at company canal.	Backwater gauge in company canal.	River gauge, 376 feet above center line of Spur No. 1.	Backwater gauge, 376 feet above Spur No. 1.	River gauge, 345 feet below center line of Spur No. 2.	Backwater gauge, 345 feet below center line of Spur No. 2.	River gauge, 1,840 feet below center line of Spur No. 2.	Gauge opposite bank of river from crevasse.	Carrollton gauge.	Total width of crevasse.	Increase on upper side.	Increase on lower side
1891.												
Apr. 11	14.49	8.06	14.72	9.94	14.41	9.44	14.27	14.29	14.90	1,039.0	0.0	4.0
12	14.59	8.11	14.72	9.89	14.36	9.44	14.27	14.29	14.95	1,045.0	4.0	2.0
13	14.54	8.11	14.72	9.94	14.31	9.40	14.27	14.19	14.70	1,060.0	9.0	6.0
14	14.59	8.21	14.67	9.99	14.41	9.44	14.27	14.19	14.80	1,092.0	23.0	9.0
15	14.54	8.21	14.72	9.99	14.31	9.49	14.17	14.14	14.65	1,097.0	5.0	0.0
16	14.47	8.21	14.57	9.99	14.06	9.54	14.12	14.09	14.65	1,109.0	0.0	12.0
17	14.44	8.31	14.52	10.09	14.01	9.59	14.07	14.14	....	1,118.0	0.0	9.0
18	14.49	8.31	14.52	9.99	14.01	9.54	14.07	13.99	....	1,128.0	2.0	8.0
19	14.39	8.31	14.42	9.99	13.61	9.54	13.97	13.94	....	1,142.0	3.0	11.0
20	14.39	8.31	14.42	10.09	13.51	9.59	13.97	13.99	14.70	1,155.0	0.0	13.0
21	14.44	8.41	14.47	10.09	(*)	9.59	14.07	14.04	14.90	1,163.0	2.0	6.0
22	14.44	8.41	14.52	10.19	....	9.59	14.12	14.04	14.80	1,173.0	3.0	7.0
23	14.49	8.51	14.72	10.14	....	9.69	14.12	14.14	....	1,182.0	0.0	9.0
24	14.49	8.41	14.72	10.14	....	(†)	14.12	14.14	14.80	1,198.0	0.0	16.0
25	14.54	8.51	14.62	10.14	....	....	14.17	14.14	14.80	1,208.0	0.0	10.0
26	14.24	8.41	14.22	10.09	....	....	14.07	14.04	14.70	1,221.0	0.0	13.0
27	14.49	8.51	14.42	10.14	....	....	14.02	13.99	14.70	1,246.0	0.0	25.0
28	14.49	8.56	14.67	10.19	....	....	14.07	14.09	14.75	1,273.0	16.0	11.0
29	14.44	8.56	14.57	10.19	....	....	14.07	14.04	14.65	1,295.0	8.0	14.0
30	14.29	9.51	14.42	10.14	....	....	13.92	13.94	14.50	1,321.0	4.0	22.0
May 1	14.24	8.51	14.32	10.09	....	....	13.92	13.89	14.55	1,322.0	0.0	1.0
2	14.24	8.56	14.32	10.14	....	....	13.87	13.89	14.50	1,352.0	0.0	30.0
3	14.14	8.61	14.27	10.14	....	....	13.87	13.84	14.40	1,382.0	3.0	27.0
4	14.19	8.61	14.22	10.19	....	....	13.87	13.84	14.50	1,414.0	2.0	30.0
5	14.09	8.66	14.19	10.14	....	....	13.72	13.74	14.40	1,444.0	4.0	26.0
6	14.19	8.66	14.22	10.24	....	....	13.87	13.94	14.45	1,471.0	3.0	24.0
7	14.24	8.81	14.47	10.29	....	....	13.92	13.99	14.50	1,508.0	6.0	31.0
8	14.19	8.81	14.37	10.39	....	....	13.62	13.94	14.40	1,547.0	3.0	36.0
9	14.09	8.76	14.22	10.29	....	....	13.72	13.74	14.40	1,564.0	2.0	15.0
10	13.84	8.66	Dry	10.24	....	....	13.57	13.54	14.30	1,576.0	3.0	9.0
11	13.79	8.66	....	10.19	....	....	13.47	13.49	14.20	1,582.0	0.0	6.0
12	13.64	8.66	....	10.24	....	....	13.37	13.49	14.00	1,594.0	3.0	9.0
13	13.59	8.61	....	10.14	....	....	13.27	13.29	13.80	1,602.0	0.0	8.0
14	13.49	5.51	....	10.09	....	....	13.17	13.14	13.70	1,610.0	0.0	8.0
15	13.39	8.51	....	10.04	....	....	13.02	13.04	13.60	1,621.0	2.0	9.0
16	13.19	8.41	....	9.99	....	....	12.84	12.79	13.45	1,625.0	0.0	4.0
17	13.04	8.31	....	9.94	....	....	12.67	12.69	13.30	1,636.0	3.0	8.0

* Caved in crevasse. † Washed out.

Date.	River gauge at company canal.	Backwater gauge, in company canal.	River gauge, 1,840 feet below center line of Spur No. 2.	Backwater gauge, 1,840 feet below Spur No. 2.	Gauge on opposite bank of river from crevasse.	Carrollton gauge.	Total width of crevasse.	Increase on upper side.	Increase on lower side.
1891.									
May 18	12.74	8.16	12.47	9.46	12.49	13.20	1,639.0	0.0	3.0
19	12.59	8.01	12.22	9.36	12.19	12.90	1,644.0	0.0	5.0
20	12.29	7.86	12.00	9.29	11.99	12.45	1,649.0	2.0	3.0
21	11.99	7.66	11.75	9.11	11.69	12.15	1,651.0	1.0	1.0
22	11.55	7.36	11.25	8.86	....	11.80	1,657.0	2.0	4.0
23	11.20	7.06	10.90	8.76	....	11.65	1,657.0	0.0	0.0
24	10.90	6.86	10.65	8.56	....	11.20	1,657.0	0.0	0.0
25	10.50	6.61	10.25	8.36	....	10.65	1,658.0	1.0	0.0
26	10.00	6.26	9.75	....	....	10.10	1,663.0	1.0	4.0
28	9.05	....	....	....	....	9.00	1,665.0	2.0	0.0
30	8.05	....	....	....	....	8.10	1,665.0	0.0	0.0
June 3	6.25	4.87	6.05	....	....	....	1,665.0	0.0	0.0

The maximum discharge of the crevasse was estimated to be about 91,000 cubic feet per second.

The above observations and measurements cost for labor $43.80, not including time of assistant engineer.

A tripod was constructed of cedar telegraph poles and placed in the crevasse. The poles were 45 feet in length, 1 foot diameter at butt, and 6 inches at top. Nine car wheels were used as ballast, three being fixed at the bottom of each leg. I think the ballast used was sufficient to hold it in the current of any crevasse if properly placed. A sketch of this tripod has been furnished your office. The cost of material was $84.64, and the cost of labor, $118.95; total, $203.59.

GAUGES.

Six bulletin-board frames for gauge stations have been constructed; the cost of frames were $119.53 for material, and for labor, $216.90. The cost of iron plates was $134.85, not including labor or paint, as they are not mounted or painted.

DISCHARGE OBSERVATIONS.

Discharge observations were commenced at Carrollton on March 4 and continued to April 16, 1891, and at foot of Henry Clay avenue, just below the Ames Crevasse, from April 3 to 14. Thirty-five observations were taken at Carrollton and eight at Henry Clay avenue.

The results of the observations at the Henry Clay avenue section showed abnormal variations, which were probably due to the eddies or irregularities in the current produced by the crevasse.

The following results were obtained at Carrollton:

Date.	Area.	Mean velocity per second.	Discharge per second.	Gauge.
	Sq. feet.	*Feet.*	*Cubic feet.*	
Mar. 4	169,466	6.493	1,102,225.12	14.40
6	172,768	6.706	1,158,728.68	14.50
9	172,438	6.358	1,096,620.08	14.65
10	171,980	6.492	1,116,598.20	14.90
12	172,963	6.481	1,121,093.31	15.30
13	173,613	6.750	1,171,894.30	15.50
14	172,778	6.920	1,195,641.96	15.60
16	173,504	6.806	1,181,017.48	16.05
17	176,009	6.886	1,212,111.82	15.90
18	175,707	6.588	1,157,592.21	15.80
19 a.m	173,986	6.787	1,180,914.51	15.65
19 p.m	174,986	6.808	1,156,350.40	15.65
20	176,050	6.703	1,183,148.87	15.55
21	176,156	6.842	1,205,349.91	15.40
23	176.934	6.589	1,165,888.94	15.30
24	177,517	6.626	1,176,167.37	15.20
26	176,763	6.506	1,150,019.27	15.30
27	176,300	6.479	1,142,271.65	15.10
28	175,978	6.523	1,148,802.38	15.00
30	178,618	6.274	1,120,634.02	14.90
31	179,298	6.469	1,160,000.37	15.05
Apr. 1	179,658	6.519	1,171,327.12	15.00
2	177,802	6,502	1,156,024.31	14.95
3	177,788	6.511	1,157,490.39	14.80
4	176,841	6.688	1,182,678.68	14.50
6	177,980	6.607	1,175,903.65	14.60
7	176,426	6.589	1,162,508.38	14.40
8	176,149	6.636	1,168,893.37	14.60
9	177,183	6.873	1,217,807.35	14.55
10	178,840	6.762	1,209,580.09	14.70
11	178,885	6.416	1,147,714.47	14.60
13	178,173	6.675	1,189,232.05	14.55
14	178,317	6,534	1,165,817.06	14.65
15	179,026	6.544	1,171,547.91	14.50
16	178,847	6.454	1,154,313.79	14.45

From date of last report until November 7, 1890, I acted as overseer to Mr. H. S. Douglas, assistant engineer.

Very respectfully, your obedient servant,

WILLIAM GARVIN,
Assistant Engineer.

Lieut. JOHN MILLIS,
Corps of Engineers, U. S. A.

The following maps and drawings are transmitted herewith:

PLATE I.—Showing location of all works of improvement in fourth district, Mississippi River.
PLATE II.—Works of improvement at junction of Red and Atchafalaya rivers.
PLATE III.—Works of improvement in New Orleans Harbor.
PLATE V.—Spur dikes in Carrollton Bend, New Orleans Harbor.
PLATE VII.—Tripod placed in Ames Crevasse.

Very respectfully, your obedient servant,

JOHN MILLIS,
First Lieut. of Engineers.

Col. C. B. COMSTOCK,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

APPENDIX F 1.

REPORT OF LIEUTENANT JOHN MILLIS, CORPS OF ENGINEERS, ON SURVEY OF MISSISSIPPI RIVER IN VICINITY OF NATCHEZ, MISSISSIPPI, AND VIDALIA, LOUISIANA.

UNITED STATES ENGINEER OFFICE,
New Orleans, La., June 29, 1891.

SIR: I have the honor to submit the following report upon a survey of the Mississippi River in the vicinity of Natchez, Miss., and Vidalia, La., made in compliance with the instructions of the Commission, with a view to determining what improvements are necessary in that locality.

The charge of the improvement of the harbors of Natchez and Vidalia was transferred by Maj. A. M. Miller, Corps of Engineers, U. S. Army, to Maj. Amos Stickney, Corps of Engineers, U. S. Army, on September 2, 1886, the latter officer being at the time on duty under the Mississippi River Commission, in charge of the fourth district. Previous to this transfer work had been begun in an attempt to arrest caving of the banks in Giles Bend and in Marengo Bend, but owing to lack of funds it was not practicable to accomplish sufficient work to be permanently effective, and nothing was done subsequent to March, 1882.

In 1889, Major Stickney submitted a plan of improvement which contemplated the protection of caving banks by means of spur dikes placed at intervals of about 1,000 feet, and his estimate of the cost of improvement was $600,000. To this plan was afterwards added a levee to be built approximately parallel to the axis of the narrow neck above Natchez, to prevent a flow of water across the neck during flood stages of the river. The cost of this levee was estimated at $100,000, making the total estimate for the project $700,000. In 1885, Major Stickney estimated that if continuous mattress revetment was substituted for spur dikes to protect the caving banks, the cost would be $1,040,000.

No construction has ever been done since this office assumed charge of the work in 1882 on account of lack of funds.

By resolution passed at its meeting of November 26, 1890, the Commission directed the district officer to have made "a resurvey of the bank line in the vicinity of Natchez, to extend from the head of Giles Bend to just below Vidalia, to sound three or four typical cross sections near the apex of each bend, to run a line of levels across the narrow neck between Giles and Cowpen bends, and to submit to the president of the Commission a report showing what improvements are required in this vicinity."

The survey as above directed was made under the immediate direction of Assistant Engineer H. S. Douglas, by Mr. H. C. Smith and Mr. E. B. Geddes, surveyors, and the map is submitted herewith.

The city of Natchez is situated on a high bluff on the east bank of the river, 103 miles below Vicksburg. It has a population of about 10,000 and is the most important town and river port below Vicksburg, excepting New Orleans.

Vidalia is situated on the low ground directly opposite Natchez and immediately on the bank of the river. It has a population of about 1,000.

Two railroads terminate at Natchez, the Natchez, Jackson and Columbus, which comes in from the eastward, and the Louisiana and Northeastern, which runs to Vidalia and comes by ferry to Natchez.

Vidalia is the terminus of the Natchez, Red River and Texas road.

The manufacturing interests of Natchez consist principally of cotton, lumber, and

cotton-seed oil mills, and a large cotton compress. There are no manufactures of any consequence in Vidalia.

The total value of receipts and shipments by river at Natchez for the year ending May 31, 1891, is estimated at $2,829,917, and the estimated amount for Vidalia is $781,976, making the value of the total annual commerce of the two places $3,611,893.

The high-water width of the Mississippi at Natchez is less than at any other point below Cairo, the distance from the bluff on the east bank to the levee opposite in front of Vidalia being only 2,170 feet. Great depth is consequently found here, and in high water a very strong current. About 6 miles above the city the river makes a bend to the eastward, and striking the line of bluffs is deflected to the westward, forming Giles Bend. It then makes a turn to the southward and eastward again (Marengo Bend) and strikes the bluff just above Natchez. It follows the foot of the bluffs for some distance below Natchez and then leaves it, taking a southwesterly course. The bend immediately above Natchez is called Cowpen Bend, and between this and Giles Bend is a peninsula about 5 miles long running out from the bluff. This peninsula is now about 4,100 feet wide in the narrowest place. It is generally low and covered with trees and a thick undergrowth, though parts of it have been cleared and are under cultivation. At high stages of the river this peninsula is entirely overflowed.

The changes in the river in this vicinity which have heretofore caused apprehension were the caving at Palo Alto Point, which it was feared might result in the moving down of Cowpen Bend and the destruction of Vidalia; the caving in Marrengo Bend, which was expected to result in the diversion of the Mississippi from its present course into Lake Concordia, and possibly the development of Bayou Cocodia as an outlet; and the formation of a cut-off across the narrow neck between Giles Bend and Cowpen Bend due to the caving in Giles Bend.

The recent survey shows that all these changes, as well as others, are still in progress, though the caving at Palo Alto Point seems to have been slight. With the exception of the caving in Giles Bend, however, none of these changes are believed to be of sufficient importance or to threaten an amount of damage which would justify their consideration in connection with works of improvement to be recommended as necessary or expedient.

The neck of the peninsula where a cut-off is feared has narrowed from 5,500 feet in 1883 to 4,100 feet, its width at the present time, and the difference in level between the water surface above and that below is now 3.4 feet. The formation of such a cut-off would undoubtedly result in very great damage not only in the immediate vicinity, but both above and below. The local result would probably be a rapid erosion and caving of the bank opposite Natchez and the partial or complete destruction of Vidalia, while a building out of the shore in front of Natchez would take place and the river would eventually assume a course as indicated on the map.

With the great increase in the river slope and velocity of the current, the effect would extend to a considerable distance up and down stream, the rate of caving would largely increase in several bends, and the inevitable result would be a large destruction of levees and real estate in the natural effort of the river to adapt itself to the new conditions.

The works of improvement which are recommended to prevent the formation of the cut-off are, protection of the caving bank in Giles Bend and a levee on the neck below this bend to prevent the river from breaking through during high water, as has previously been recommended, and some arrangement with the owner of the property by which clearing of timber and undergrowth along the caving bank shall be stopped.

Of the above, the levee should be built at once. As the neck gets narrower the slope and velocity of the current across the neck during high water will of course become greater, and the danger of the river cutting through is increasing from year to year. Though the levee will have no influence on the caving above, and would eventually be destroyed if other means were not resorted to to stop caving, its effect while it does last will be positive and its life would be sufficiently great to justify the expenditure as a temporary expedient only, judging by the standard of endurance often adopted for levees which are built for the prevention of overflow at other places on the river.

The estimate for the levee is $66,300.

With regard to the prevention of caving in Giles Bend the conditions and recommendations can not be stated with equal positiveness, except that spur dikes are not recommended since the efficiency and economy of this method of protecting caving banks, when applied under conditions similar to those obtaining in Marengo Bend, are not believed to have been as yet satisfactorily established, and it is believed that the safest form of protection in the present state of knowledge and experience on the subject would be a continuous mattress and stone revetment. No practicable method of preventing the clearing off of the neck is suggested short of purchasing

the land outright, an investment which it is not believed would prove economical or judicious at present.

To afford reasonable prospect of the success of the bank protection the funds available should be sufficient to complete enough of the work to be effective in one working season and to continue the work thereafter as rapidly as possible and without interruption. The advisability of undertaking it at all under less favorable conditions would be to my mind a matter of considerable doubt.

The following is the total estimate for the work recommended:

For plant:	
Ten large barges, at $3,000	$30,000
Four small barges, at $1,500	6,000
One steam tug	10,000
One steam launch	3,000
Two quarter boats, at $3,500	7,000
Tools, skiffs, etc	9,000
Total for plant	65,000
For constructing 16,000 linear feet of bank revetment in Giles Bend, at $25 per foot	400,000
For care and repairs to plant	10,000
For levee to prevent scour across neck during high water, 255,000 cubic yards, at 26 cents	66,300
Total for improvement	541,300

Should the other works in the district take such shape as to permit the use of portions of the plant now on hand the above estimate for new plant might be somewhat reduced.

The proposed levee on the neck between Giles Bend and Cowpen Bend is believed to be urgently necessary and its construction at once is recommended if funds from the present allotment for levees can be made available. By building this levee it is estimated that the formation of a cut-off can be postponed with certainty for 15 years with no further work of improvement, and without the levee the cut-off is liable to occur at any flood season.

The following commercial statistics of Natchez and Vidalia for the year ending May 31, 1891, were compiled by Assistant Engineer Hardee:

Statement showing the approximate receipts and shipments of freight by river from June 1, 1890, to June 1, 1891, at Natchez, Miss. and Vidalia, La., compiled from information derived from the commercial exchanges of those places and the business houses and landings where the steamboats receive and discharge cargoes:

NATCHEZ, MISSISSIPPI.

Receipts.

Number of steamboats in the trade	38
Number of times arrived	819
Number of barges	52
Total cargo arrived (tons)	106,961
Value of same	$1,734,027

ARTICLES OF CARGO.

Cotton	bales	15,500	Cotton seed	sacks	65,307
Lumber	feet, B. M.	7,000,000	Coal	bushels	1,250,000
Wood	cords	960	Sacks, empty	bundles	1,150
Corn meal	barrels	37,482	Flour	barrels	19,156
Oats	sacks	101,450	Corn	sacks	65,840
Bran	do	13,189	Wet barrels	number	987
Wrapping paper	packages	605	Sash, doors, and blinds	pkgs	769
Hardware	do	10,374	Groceries	do	18,780
Wooden ware	do	7,628	Miscellaneous	do	1,150

Shipments.

Number of steamboats in the trade	38
Number of times departed	717
Total cargo shipped (tons)	28,104
Value of same	$1,095,890

ARTICLES OF CARGO.

Cotton ... bales..	10,527	Cotton cloth ... yards..	764,575
Cotton-seed oil ... gallons..	154,677	Cotton-seed meal ... sacks..	12,305
Cotton linters ... pounds..	176,775	Sacks, empty ... number..	2,084
Lumber ... feet, B. M..	1,490,600	Shingles ... do....	910,500
Ice ... tons..	1,998	Corn meal ... barrels..	31,462
Flour ... barrels..	14,576	Oats ... sacks..	73,497
Corn ... sacks..	42,842	Bran ... do....	7,670
Wet barrels ... number..	944	Wrapping paper ... bundles..	369
Sash, doors, and blinds.pkgs..	653	Hardware ... packages..	8,558
Groceries ... do....	15,683	Wooden ware ... do....	5,976
Cotton batting ... bales..	583	Bricks ... number..	215,600
Miscellaneous ... packages..	1,052		

RECAPITULATION FOR NATCHEZ, MISSISSIPPI.

Total cargo received and shipped (tons)	135,065
Total value of cargo received and shipped	$2,829,917

VIDALIA, LOUISIANA.

Number of steamboats in the trade	38
Number of times they have landed	819
Number of barges	2
Total cargo received and shipped (tons)	12,392
Total value of cargo received and shipped	$781,976.75

ARTICLES OF CARGO.

Cotton ... bales..	12,560	Cotton seed ... sacks..	58,400
Cross ties ... number..	5,147	Bran ... do....	900
Corn ... sacks..	12,519	Oats ... do....	15,465
Corn meal ... barrels..	5,314	Flour ... barrels..	2,758
Hay ... bales..	1,870	Liquors ... do....	150
Miscellaneous ... packages..	7,200	Meat (salt) ... boxes..	175
Furniture ... do....	3,500	Sugar ... barrels..	410
Molasses ... barrels..	325	Groceries ... packages..	3,325
Lime ... do....	180	Hardware ... do....	1,275
Coal ... bushels..	24,000	Lumber ... feet, B. M..	196,750

The nearest port of entry to Natchez is Vicksburg, Miss.

IMPROVING MISSISSIPPI RIVER AT NATCHEZ AND VIDALIA, MISSISSIPPI AND LOUISIANA.

NATCHEZ, MISSISSIPPI (SURVEY).

Money statement.

Amount allotted from act approved September 19, 1890	$1,500.00
June 30, 1891, amount expended during fiscal year	1,385.31
July 1, 1891, balance unexpended	114.69
Amount that can be profitably expended in fiscal year ending June 30, 1893	250,000.00
Submitted in compliance with requirements of sections 2 of river and harbor acts of 1866 and 1867.	

The report of Assistant Engineer H. S. Douglas on the survey accompanies and forms a part of this report.

JOHN MILLIS,
First Lieut. of Engineers.

Col. C. B. COMSTOCK,
Corps of Engineers, U. S. A.,
President Mississippi River Commission.

REPORT OF MR. H. S. DOUGLAS, ASSISTANT ENGINEER.

NEW ORLEANS, LA., *June 30, 1891.*

SIR: I have the honor to submit the following report upon the survey of the Mississippi River in the vicinity of Natchez, Miss., and Vidalia, La.

The length of river to be surveyed (about 18 miles) and the amount allotted for the purpose bore such relation that it was necessary to cover the greatest amount of territory with the least possible expenditure of money. In consequence the methods pursued, while giving generally good results, were not of an extremely accurate character. They were:

A transit and stadia traverse line on magnetic meridian of either bank, such topography as was essential being located in the same way. These traverse lines were tied onto angles in the existing old levees and to the stone lines of the Commission where possible, to identify the lines for comparative purposes. Twelve sections of the river were sounded, the soundings being located by the intersections of ranged lines and transit angles, which method gives results containing a certain element of inaccuracy. A line of levels was run across the neck of land between Giles and Cowpen bends, and a line for a levee to prevent the flow of water across the neck was staked out. All levels were connected with the zero of the Natchez gauge and soundings reduced to the same plane.

The following is a summary of the work done:

Length of traverse line	miles	41
Length of level lines	do	10
Number of soundings taken and located		506
Area covered by survey	square miles	16

For comparative purposes the survey made by the Mississippi River Commission in February, 1883, has been used. The comparison shows the following changes:

On the upper side of the neck in Giles Bend the bank is caving for a distance of 30,000 feet. The maximum recession of the bank in this bend is 1,600 feet. The total area of land destroyed by the caving of the river banks is about 661 acres, which multiplied by the average depth of the river below the bank gives 86,000,000 cubic yards of material removed by the action of the river since February, 1883.

The next material change noted is on the west bank of the river in the Marengo Bend. Here the length of bank where caving has taken place is 30,000 feet. The maximum recession of bank is 4,500 feet, and the area of land destroyed is about 1,605 acres. The amount of material removed by the action of the river since 1883 is about 193,000,000 cubic yards. The lower end of the Marengo Bend is at Palo Alto Point, about 2 miles above the town of Vidalia. In 1884 the rapid caving on the upper side of the point caused apprehension that the river would cut its way through and possibly destroy the town of Vidalia. A survey was made, and the alarm at that time considered well founded. Work to prevent further erosion of the bank was recommended, but nothing was done. Since that time the channel of the river has slightly changed, and the rate of caving on the upper side of Palo Alto Point has decreased to such an extent that there does not appear to be immediate danger.

No considerable change is shown in the bank lines at other points, but at the lower end of the town of Vidalia some caving has taken place within the last 2 years. The extent of the caving at this point is not very great, but on account of expensive improvements on the immediate bank and the greater value of land, it has excited more interest than elsewhere.

I think that the great danger now threatening the harbors of Natchez and Vidalia is the possible cut-off through the neck of land between Giles Bend and Cowpen Bend. Such a cut-off can not possibly be beneficial and is reasonably certain to be injurious, perhaps destructive, to the river commerce of both cities. The extent of such injury or the exact results can not now be definitely stated. It would be likely to cause the total destruction of the present site of Vidalia and create a sand bar in front of Natchez. But this would not be the possible extent of the injury to the country in the vicinity. The line of levels run across the neck at about the time when the river was rising and overflowing the natural bank showed a fall of 3.42 feet in 4,100 feet, the distance across

the neck. It is absolutely certain that this great slope would not remain in the limited distance mentioned, but would be prorated over a long distance above and below the cut-off. Increased slope means increased velocity, and increased velocity causes the more rapid caving of the river banks. Levees now considered reasonably permanent will be destroyed and have to be replaced by higher and more expensive embankments. When it is remembered that the King Point Cut-off, which occurred in 1884, is but a few miles above, the effect of both can be surmised. It will practically destroy the river front of Concordia Parish for levee purposes, as the Palmyra and Centennial cut-offs have destroyed the front of Tensas Parish. The actual damage that would be caused by the prospective cut-off can not be stated, even approximately, but it would undoubtedly be far greater than the cost of such work as would be necessary to prevent the cut-off across the neck of land between Giles and Cowpen bends.

Very respectfully, your obedient servant,

H. S. DOUGLAS,
Assistant Engineer.

Lieut. JOHN MILLIS,
Corps of Engineers, U. S. A.

APPENDIX A A A.

ANNUAL REPORT OF THE MISSOURI RIVER COMMISSION FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

MISSOURI RIVER COMMISSION,
St. Louis, Mo., July 9, 1891.

SIR: The Missouri River Commission beg leave to submit herewith their annual report for the fiscal year ending June 30, 1891.

At the date of the last annual report all work of construction had been suspended for lack of funds, and the late date at which the new appropriation was made did not admit of its resumption, except in a few cases, until the spring of the current year, since which time operations have been much interfered with by high water. Everything is, however, in readiness, and as soon as the water recedes sufficiently all the works contemplated will be vigorously pushed.

The allotments of the appropriation of September 19, 1890, recommended by the Commission and approved by the Secretary of War, are as follows:

Office and traveling expenses and salaries of Commission	$40,000
Maintenance of gauges, collection of physical data, and publications	25,000
Surveys and examinations between Sioux City and the mouth of river	55,000
Care and repair of plant	35,000
Operating snag boat	35,000
Extending and completing revetment already begun in the vicinity of Council Bluffs, Iowa	85,000
Completing revetment on Nebraska City Island	10,500
Continuation and completing revetment in Belmont Bend	101,000
Repair and maintenance of works in the vicinity of Kansas City	65,500
Systematic improvement in first reach	348,000
Total	800,000

SURVEYS AND EXAMINATIONS.

The secondary triangulation of the Missouri Valley was finished during the season, and is now complete from the mouth of the river to the Three Forks. One party extended the system from Fort Benton to Three Forks, Mont., a distance of 256 miles, while a second party closed the gap between Sioux City, Iowa, and Fort Leavenworth, Kans., a distance of 385 miles.

A complete survey of the river was also made from the Three Forks to Stubbs Ferry, and from Sun River to Fort Benton, Mont., a distance in all of 125 miles. The same party also went over the 131 miles of river between Stubbs Ferry and Sun River, revising and verifying the previous survey of Captain Maguire, U. S. Engineers, and connecting it to the valley triangulation. Permanent bench-marks were also established throughout the whole distance of 256 miles.

During the previous season a survey had been made from Fort Benton to Coal Banks, a distance of 40 miles, and during the past season Lieutenant Chittenden, in charge of the upper river, was directed to continue this survey, under a special allotment, as far downstream as time and funds would allow. The party reached Wolf Point, Mont., 395 miles below Benton. They also extended the permanent bench-marks from Trover Point to Wolf Point, a distance of 157 miles. There still remains to be executed about 700 miles of topographical survey between Wolf Point, Mont., and Pierre, S. Dak., and the permanent bench-marks are lacking between Wolf Point and Sioux City, a distance of about 1,050 miles. This work has passed under the charge of the Engineer Department, U. S. Army, and it is understood will be completed as speedily as possible.

The published maps of the Missouri River between Sioux City and the mouth depend upon surveys made in 1878 and 1879. Since then so many changes have occurred as to render these maps of little value for reference, and as soon as the new appropriation became available a new shore-line survey was ordered from Sioux City to the mouth of the river. This was carried out last fall, the whole distance of 803 miles being covered in 15 weeks.

The entire survey work of the season, therefore, covers 1,374 miles of river, in addition to numerous local surveys made for special purposes. Twenty-three gauges have been maintained and read, and the study and reduction of physical data has been continued.

For details see report of secretary of the Commission, Appendix A.

CONSTRUCTION.

Work between Fort Benton, Montana, and Sioux City, Iowa.—Owing to the lack of funds nothing was done here. Under the provisions of the last river and harbor bill the work passed into the charge of the Engineer Department, U. S. Army, and was formally turned over November 30, 1890. (See report of Lieut. H. M. Chittenden, U. S. Engineers, Appendix B.)

Work between Sioux City, Iowa, and the mouth of Missouri River.—For details, see Appendices C, C 1, D, and E.

Sioux City, Iowa.—The dikes constructed in front of the city to arrest the severe erosion in progress have satisfactorily accomplished the work expected of them. Some slight repairs and additions were made during the current season to increase their efficiency. A small balance still remains to the credit of this work, which is held to meet possible contingencies.

Omaha, Nebraska.—No work was done at this point during the past season. An allotment has been made for extending and completing the revetment of the left bank near Council Bluffs, which work will be carried out during the present season.

Plattsmouth, Nebraska.—The special appropriation for this place made by the act of 1888 remained unexpended at the close of last fiscal year. As no needed work could possibly be accomplished by its expenditure in this vicinity, the Commission, under authority of the act of 1890, recommended that the money be transferred to the allotment for St. Joseph, Mo. This recommendation was approved by the Secretary of War, and the funds have been expended on work at that locality.

Nebraska City, Nebraska.—The work contemplated here is the protection of the shore of Nebraska City Island above the railroad bridge. This work can only be done as the bar in front of this bank is cut away

by the river. During the past season 940 feet of bank was protected, and funds are held available for prosecuting the work as occasion offers.

Rulo, Nebraska.—Work at this place, under special appropriation, was in progress at date of last report. The revetment of 4,922 feet of the left bank above the railroad bridge was completed July 17, 1890. Nothing further seems necessary.

St. Joseph, Missouri.—During the past season certain changes in the channel above the improved portion of the river brought a very severe strain on the revetment in Bon Ton Bend, and threatened the destruction of all the work executed in this vicinity. The balance remaining available for this work was not sufficient to meet the danger, and upon the recommendation of the Commission the balance remaining of the special appropriation for Plattsmouth was transferred to this work. A system of pile dikes designed to control the channel above Bon Ton Bend was begun in October and carried on till stopped by ice, December 24. Work was resumed in the spring and carried on till stopped by high water in June. Work will be resumed when the water recedes sufficiently, and will probably be completed this season.

The revetment of Elwood Point, opposite St. Joseph, constructed in former years, has never been carried to a junction with the right-hand bluffs. As the bank above this revetment is now caving badly, the Commission have made an allotment for closing the gap and thus completing the work. A beginning was made this season, but was stopped by high water when 700 feet had been constructed. Work will be resumed when the water has fallen sufficiently.

Atchison, Kansas.—The dikes constructed at this place to control and direct the channel have accomplished the object intended in a very satisfactory manner. Some slight repairs have been executed. During the present high water a cut-off has taken place a few miles above the works, but it is yet too early to see what its effect will be upon the river in this vicinity.

Leavenworth, Kansas.—No further work has been done here, the special appropriation made in 1888 being exhausted. At last accounts the work was all in good shape.

Kansas City, Missouri.—Nothing was done in this vicinity during the past season. In the spring of 1890 work was resumed, but has been much interrupted by high water. The operations contemplated consist of repairs and protection of dikes and extension of revetment in Little Platte Bend, repairs to Kaw Bend revetment, extension of Harlem and Kansas City dikes, and construction of revetment in front of Harlem. This work will probably be completed during the current season.

Miami, Missouri.—Nothing has been done here, the appropriation being exhausted. The work is in fair condition and has accomplished the object intended.

Arrow Rock, Missouri.—Nothing has been done here, the appropriation being exhausted. The revetment built in 1889 on the left bank in Nigger Bend was, at last reports, in good condition.

REMOVAL OF OBSTRUCTIONS.

The snagboat belonging to the Commission resumed work in the Missouri River August 10, 1890, and reached Kansas City October 1. She then returned to the mouth of the river and worked upstream from October 15 to November 7. At that date she turned back from Portland, Mo., and worked down to the mouth. She arrived at St. Louis November 21, and was soon after laid up for the winter. She again

left St. Louis March 11, worked up to Kansas City, and returned to the mouth. She started up the river again May 15 and by June 3 had reached Glasgow. Here the rapidly rising river interfered so much with her work that she was ordered in and laid up. As soon as the river falls sufficiently work will be resumed. The vigorous prosecution of this work during low stages of water has been of immense benefit to navigation.

Table of work done by snag boat.

Name of river.	Snags destroyed.		Trees cut.	Drift piles removed.	Miles run.
	Number.	Estimated weight in tons of 2,000 pounds.			
Missouri	2,184	25,501.1	1,079	9	3,172

The act of September 19, 1890, directs that with certain specified exceptions the appropriation be expended by the Secretary of War "in the systematic improvement of the river from its mouth up, according to the plans and specifications of the Missouri River Commission, to be approved by him in reaches to be designated by them."

In compliance with the provisions of this act, the Commission recommended that, for purposes of systematic improvement, the Missouri River between Sioux City and the mouth be divided into the following reaches:

	Miles.
First reach, mouth of river to Osage River	137
Second reach, Osage River to Grand River	110
Third reach, Grand River to Kaw River	131
Fourth reach, Kaw River to Nemaha River	148
Fifth reach, Nemaha River to Platte River	105
Sixth reach, Platte River to Sioux City	162

They also recommended that the improvement of the First Reach be first undertaken.

These recommendations have been approved by the Secretary of War, and preparations are being made to begin work near the mouth of Osage River as soon as the water falls sufficiently.

The Commission accept this latest legislation of Congress as an expression of their intention that the systematic improvement of the river for purposes of navigation shall be prosecuted to speedy completion. The Commission have therefore concentrated on this work all the means at their command, reserving for outside work only such sums as were absolutely needed to prevent the serious deterioration or destruction of work already executed. These drains, however, were so heavy that the sum allotted to the First Reach is a small one, in view of the importance of a rapid prosecution of the work, more especially on account of the failure to pass a river and harbor bill at the last session of Congress.

The Commission respectfully represent that in a work of this magnitude the possibility of rapid execution is of the greatest importance, not only to secure early beneficial results, but also to increase the facility and economy of construction. The Commission have no doubt that the river can be successfully improved so as to meet all reasonable demands of commerce; but, to do this, ample means will be required to

insure continuous work free from vexatious and expensive interruptions and suspensions. The following estimates are submitted:

Estimates for continuing works of improvement for the fiscal year ending June 30, 1893.

Salaries of Commission, office and traveling expenses, surveys and observations, gauges, etc	$100,000.00
Improving Missouri River between Sioux City and the mouth of the river	3,000,000.00
Total	3,100,000.00

Money statement.

July 1, 1890, balance unexpended	$232,023.89
Amount appropriated by act approved September 19, 1890	800,000.00
Cash received from overpayments refunded	10.75
	1,032,034.64
June 30, 1891, amount expended during fiscal year	280,331.49
July 1, 1891, balance unexpended	751,703.15
July 1, 1891, outstanding liabilities	38,982.48
July 1, 1891, balance available	712,720.67

Respectfully submitted.

CHAS. R. SUTER,
Lieut. Col. of Engineers,
President Missouri River Commission.
A. MACKENZIE,
Major of Engineers.
GARLAND C. BROADHEAD.
RICHARD S. BERLIN.

I concur in the foregoing report, except as to the estimate of $3,000,000 for carrying on the works during the fiscal year ending June 30, 1893. In my judgment the regular annual expenditure of $1,000,000 is all that should be undertaken until the Commission is able to submit an estimate, which shall be reasonably accurate, of the final cost of the whole improvement. As stated in its first report, "the question of cost must be determined by actual trial. * * * The trial, to be really demonstrative, must be undertaken with ample means and followed up without intermission for several years, over a continuous piece of river, the length of which must be considerable." The laws under which the Commission has been acting have not as yet permitted them to make this demonstrative trial.

O. H. ERNST,
Major, Corps of Engineers, Colonel, U. S. A.

The SECRETARY OF WAR.
(Through the Chief of Engineers, U. S. A.)

Financial statement from July 1, 1890, to June 30, 1891.

Work.	Amount available July 1, 1890.	Act of Sept. 19, 1890.	Refunded on account of overpayment.	Received by transfer from other allotments.	Totals.	Amount expended, exclusive of outstanding liabilities.	Reserved for expenses office Chief of Engineers.	Transferred to other allotments.	Total expended and transferred, etc.	In Treasury.	In hand.	Total balances June 30, 1891.
Survey of the Missouri River, above the Missouri River Falls, Fort Benton, Mont	$15,000.00				$15,000.00	$14,863.23	$25.00		$14,888.23		$111.17	$111.17
Between Fort Benton, Mont., and Sioux City, Iowa:												
Improving Missouri River between Sioux City and Fort Benton	2,587.97		$0.75		2,588.72	2,588.72			2,588.72			
Surveys between Fort Benton and Sioux City	8,639.27				8,639.27	7,548.96			7,548.96		1,090.31	1,090.31
Expenses proper of Commission, gauges and physical data	817.53				817.53	817.53			817.53			
Between Sioux City, Iowa, and mouth of river:												
Office and traveling expenses and salaries of Commission	1,250.00	$40,000.00	10.00	$2,300.00	43,560.00	14,930.02			14,930.02	$28,000.00	629.98	28,629.98
Survey of Missouri River between Sioux City and the mouth	17,306.85				17,306.85	17,240.43			17,240.43		66.42	66.42
Improving Missouri River, in vicinity of St. Joseph, Mo	4,448.63			39,368.78	43,810.46	34,281.95			34,281.95	3,361.78	6,166.73	9,528.51
Improving Missouri River in vicinity of Kansas City, Mo	903.36				903.36	903.36			903.36			
Repair and care of plant	2,803.30				2,803.30	503.30		$2,300.00	2,803.30			
Omaha, Nebr	4,073.29				4,073.29	4,073.29			4,073.29			
Sioux City, Iowa	18,093.03				18,093.03	10,470.78			10,470.78	4,638.22	2,984.03	7,622.25
Plattsmouth, Nebr	39,561.78				39,561.78		200.00	39,361.78	39,568.78			
Rulo, Nebr	7,840.51				7,840.51	7,840.51			7,840.51			
Nebraska City, Nebr	8,621.42				8,621.42	8,621.42			8,621.42			
Atchison, Kans	4,775.10				4,775.10	2,330.44			2,330.44		2,444.66	2,444.66
Leavenworth, Kans	1,387.72				1,387.72	1,387.72			1,387.72			
Miami, Mo	1,133.73				1,133.73	1,133.73			1,133.73			
Arrow Rock, Mo	346.72				346.72	356.72			346.72			
Extending and completing revetment in vicinity of Council Bluffs, Iowa		85,000.00			85,000.00	2,722.30			2,722.30	82,000.00	277.70	82,277.70
Completion of revetment on Nebraska City Island		10,500.00			10,500.00					5,500.00	5,000.00	10,500.00
Continuation and completion of revetment in Belmont Bend		101,000.00			101,000.00	2,899.14			2,899.14	98,000.00	100.86	98,100.86
Repair and maintenance of works in vicinity of Kansas City		35,500.00		30,000.00	65,500.00	4,771.74			4,771.74	60,500.00	228.26	60,728.26

Systematic improvement in first reach	....	378,000.00	....	....	378,000.00	11,833.68	....	30,000.00	41,833.68	383,000.00	3,166.32	386,166.32
Maintenance of gauges, collection of physical data, and publications	....	25,000.00	....	....	25,000.00	6,496.45	....	....	6,496.45	18,000.00	503.55	18,503.55
Surveys and examinations between Sioux City and the mouth of the river	....	55,000.00	....	....	55,000.00	26,364.68	....	....	26,364.68	27,500.00	1,135.32	28,635.32
Care and repair of plant	....	35,000.00	....	....	35,000.00	29,245.24	....	....	29,245.24	4,000.00	1,754.76	5,754.76
Removing obstructions in Missouri River from St. Joseph, Mo., to mouth	63,509.75	35,000.00	....	....	98,509.75	36,807.27	160.00	....	36,967.27	61,340.00	202.48	61,542.48
Total	203,100.01	800,000.00	10.75	71,661.78	1,074,772.54	251,022.61	385.00	71,661.78	323,069.39	725,840.00	25,863.15	751,703.15

Detailed statement July 5, 1884, to June 30, 1891.

Work.	Balances of appropriations of 1882.	Appropriations and allotments.	From sales, etc.	Total available.	Expended to June 30, 1891.	In Treasury.	In hand.	Total balances June 30, 1891.
Survey of the Missouri River above the Missouri River Falls, Fort Benton, Mont.		$15,000.00		$15,000.00	$14,888.23		$111.17	$111.17
Between Fort Benton, Mont., and Sioux City, Iowa:								
Office and inspection expenses of district officer	$2,000.00	4,749.00		6,749.00	6,749.00			
Purchase and repair of plant	2,000.00	58,751.00		60,751.00	60,751.00			
Work below Fort Benton		31,500.00		31,500.00	31,500.00			
Improving Missouri River between Sioux City and Fort Benton		48,250.00	$0.75	48,250.75	48,250.75			
Survey between Fort Benton and Sioux City		73,250.00		73,250.00	72,159.69		1,090.31	1,090.31
Office expenses and expenses of Commission		5,000.00	53.24	5,053.24	5,053.24			
Expenses proper of Commission, gauges and physical data		3,500.00	20.62	3,520.62	3,520.62			
	4,000.00	225,000.00	74.61	229,074.61	227,984.30		1,090.31	1,090.31
Survey of Missouri River from its mouth to Fort Benton	8,844.39			8,844.39	8,844.39			
Between Sioux City, Iowa, and mouth of river:								
Office and traveling expenses and salaries of Commission		85,000.00	663.86	85,663.86	57,033.88	$28,000.00	629.98	28,629.98
Additional surveys and establishment of permanent bench-marks below Sioux City		48,000.00		48,000.00	48,000.00			
Care of plant, preservation and observation of gauges, and collection and compilation of physical data		37,000.00		37,000.00	37,000.00			
Purchase of towboat		1,100.00		1,100.00	1,100.00			
Improving Missouri River in vicinity of Kansas City (at Parkville, Mo.)		491,851.96	42.36	491,894.32	491,894.42			
Improving Missouri River in vicinity of St. Joseph		287,269.98	13.28	287,283.10	277,754.59	3,361.78	6,166.73	9,528.51
Improving Missouri River in vicinity of Kansas City, Mo.		106,150.00		106,150.00	106,150.00			
Construction of plant		57,064.84		57,064.84	57,064.84			
Special surveys		14,500.00		14,500.00	14,500.00			
Expenses proper of Commission, gauges and physical data		83,800.00	142.47	83,942.47	83,942.47			
Survey of Missouri River between Sioux City and the mouth		83,775.00		83,775.00	83,708.58		66.42	66.42
Repair and care of plant		97,700.00		97,700.00	97,700.00			
Omaha, Nebr.		120,736.64		120,736.64	120,736.64			
Sioux City, Iowa		80,411.67		80,411.67	72,789.42	4,638.22	2,984.03	7,622.25
Rulo, Nebr.		39,980.49		39,980.49	39,980.49			
Nebraska City, Nebr.		60,298.92		60,298.92	60,298.92			
Atchison, Kans.		60,639.14		60,639.14	58,194.48		2,444.66	2,444.66
Leavenworth, Kans.		60,213.71		60,213.71	60,213.71			
Miami, Mo.		19,787.67		19,787.67	19,787.67			
Arrow Rock, Mo.		36,294.98		36,294.98	36,294.98			
Extending and completing revetment in vicinity of Council Bluffs, Iowa		85,000.00		85,000.00	2,722.30	82,000.00	277.70	82,277.70

Completion of revetment on Nebraska City Island	....	10,500.00	....	10,500.00	....	5,500.00	5,000.00	10,500.00
Continuation and completion of revetment in Belmont Bend	....	101,000.00	....	101,000.00	2,899.14	98,000.00	100.86	98,100.86
Repair and maintenance of works in vicinity of Kansas City	....	65,500.00	....	65,500.00	4,771.74	60,500.00	228.26	60,728.26
Systematic improvement in first reach	....	348,000.00	....	348,000.00	11,833.68	333,000.00	3,166.32	336,166.32
Maintenance of gauges, collection of physical data, and publications	....	25,000.00	....	25,000.00	6,496.45	18,000.00	503.55	18,503.55
Surveys and examinations between Sioux City and the mouth of the river	....	55,000.00	....	55,000.00	26,364.68	27,500.00	1,135.32	28,635.32
Care and repair of plant	....	35,000.00	....	35,000.00	29,245.24	4,000.00	1,754.76	5,754.76
	....	2,493,436.30	861.81	2,494,298.11	1,805,339.52	664,500.00	24,458.59	688,958.59
Removal of snags and other obstructions (appropriation of 1886)	1,982.80	153,425.00	....	155,407.80	93,865.32	61,840.00	202.48	61,542.48
Grand total	14,827.19	2,890,000.00	936.42	2,905,763.61	2,154,060.46	725,840.00	25,863.15	751,703.15

Consolidated statement, July 5, 1884, to June 30, 1891.

Act of July 5, 1884		$640,000.00
Act of August 5, 1886		375,000.00
Act of August 11, 1888		1,000,000.00
Act of February 22, 1890		75,000.00
Act of September 19, 1890		800,000.00
Total specific appropriations		2,890,000.00
Balances from former appropriations:		
Act of August 2, 1882, applied to works above Sioux City, Iowa	$4,000.00	
Survey Missouri River from mouth to Fort Benton	8,844.39	
Act of August 5, 1886, applied to removing obstructions from Missouri River	1,982.80	
Total balances		14,827.19
Received from sales and deposits		936.42
Total available		2,905,763.61
Expended		2,154,060.46
Unexpended balance June 30, 1891		751,703.15
Outstanding liabilities June 30, 1891		38,982.48
Balance available July 1, 1891		712,720.67

List of civilian engineers employed on work of river and harbor improvement in charge of Missouri River Commission from July 1, 1890, to June 30, 1891, inclusive, under the river and harbor acts of July 5, 1884, (survey of Missouri River above Missouri River Falls, Fort Benton, Mont., August 11, 1888 (improving Missouri River), and September 19, 1890 (improving Missouri River from its mouth to Sioux City, Iowa).

Name and residence.	Time employed. Mos.	Time employed. Days.	Compensation per month.	Where employed.
S. Waters Fox, St. Joseph, Mo	2	0	$250.00	St. Joseph, Mo.
	10	0	200.00	Do.
Samuel H. Yonge, Kansas City, Mo.	2	0	250.00	Kansas City, Mo.
	10	0	200.00	Do.
G. A. Marr, St. Louis, Mo	1	2	250.00	In the field.
	5	13	225.00	Do.
	5	15	200.00	St. Louis, Mo.
O. B. Wheeler, St. Louis, Mo	4	0	225.00	In the field.
	8	0	200.00	St. Louis, Mo.
D. W. Wellman, St. Louis, Mo	11	9	200.00	St. Louis, Mo., and in the field.
Charles F. Potter, Omaha, Nebr	12	0	200.00	Omaha, Nebr.
James A. Seddon, St. Louis, Mo	7	23½	200.00	St. Louis, Mo.
	2	19	125.00	Do.
A. H. Blaisdell, St. Louis, Mo	12	0	200.00	Do.
F. M. Tower, Detroit, Mich	2	0	175.00	In the field and at St. Louis, Mo.
R. A. Crawford, Kansas City, Mo	1	0	162.50	Kansas City, Mo., and in the field.
	1	2	137.50	Do.
	8	8	125.00	Do.
	0	8	100.00	Do.
J. C. Meredith, Nebraska City, Nebr	11	0	150.00	Nebraska City, Nebr., and in the fi
A. H. Weber, Kansas City, Mo	2	18	150.00	In the field and at Kansas City, M
	5	18	125.00	Do.
R. H. Bacot, Kansas City, Mo	0	14	150.00	Do.
	8	28	125.00	Kansas City, Mo.
Ed. Jones, Omaha, Nebr	1	0	150.00	Omaha, Nebr., and in the field.
	8	0	125.00	Do.
	3	0	75.00	Do.
A. N. Darrow, St. Louis, Mo	1	0	137.50	Kansas City, Mo.
O. H. B. Turner, St. Louis, Mo	8	0	125.00	St. Louis, Mo., and in the field.
	3	0	110.00	Do.
I. D. McKown, St. Louis, Mo	1	11	125.00	In the field.
	7	24	100.00	St. Louis, Mo., and in the field.
V. Schindler, St. Louis, Mo	4	0	125.00	St. Louis, Mo.

List of civilian engineers employed on work of river and harbor improvement in charge of Missouri River Commission, etc.—Continued.

Name and residence.	Time employed.	Compensation per month.	Where employed.
	Mos. Days.		
E. A. D. Parker, Nebraska City, Nebr.	1 0	$125.00	At Omaha, Nebr., and in the field.
	1 29	100.00	Do.
R. F. Grady, St. Louis. Mo	7 18	125.00	St. Louis, Mo., and in the field.
B. C. Collier, Kansas City, Mo	0 23	120.00	In the field.
C. W. Williams, St. Charles, Mo	3 23	100.00	Do.
E. D. Williams, St. Louis, Mo	6 0	100.00	St. Louis, Mo., and in the field.
	1 0	90.00	Do.
T. C. Thomas, Vicksburg, Miss	3 1	100.00	In the field.
J. L. Sanders, St. Louis, Mo	6 10½	100.00	Do.
J. W. Woermann, Milan, Ill	2 18	100.00	Do.
H. R. Abry, Leavenworth, Kans	4 4	100.00	Do.
S. W. Benedict, St. Joseph, Mo	0 27	100.00	Do.
Frank V. Potter, St. Joseph, Mo	4 25	100.00	St. Joseph, and in the field.
	1 4	75.00	Do.
W. C. Simmons, Kansas City, Mo	4 10	100.00	In the field.
C. H. McClelland, Kansas City, Mo	1 1	100.00	Do.
Wm. M. Erickson, Omaha, Nebr	1 29	100.00	Do.
Konrad Miller, Kansas City, Mo	4 11	100.00	Do.
S. E. Packard, Omaha, Nebr	0 20	100.00	Do.
G. T. Nelles, Leavenworth, Kans	2 25	100.00	Do.
Chas. A. Sheppard, Omaha, Nebr	1 29	100.00	Do.
Wm. Brown, Omaha, Nebr	1 14	100.00	Do.
C. Morton Ayers, St. Joseph, Mo	0 21	90.00	Do.
H. R. Fardwell, St. Joseph, Mo	0 2	90.00	Do.
L. Y. Kerr, Independence, Mo	4 4	90.00	Do.
R. L. Faris, Washington, D. C	6 26	90.00	St. Louis, Mo., and in the field.
John H. Field, St. Louis, Mo	0 8	90.00	Do.
W. B. Hasen, St. Joseph, Mo	1 21	90.00	In the field.
	0 26	75.00	Do.
Will T. Morton, Piedmont, Ala	1 0	90.00	Do.
	0 22	75.00	Do.
W. G. Potter, Omaha, Nebr	0 23	75.00	Omaha, Nebr.

APPENDIX A.

ANNUAL REPORT OF SECRETARY MISSOURI RIVER COMMISSION, 1891.

OFFICE MISSOURI RIVER COMMISSION,
St. Louis, Mo., June 30, 1891.

SIR: I have the honor to submit the following annual report of the work in charge of the secretary of this Commission for the fiscal year ending June 30, 1891.

Very respectfully, your obedient servant,

JAMES C. SANFORD,
First Lieutenant of Engineers, Secretary.

Lieut. Col. CHAS. R. SUTER,
Corps of Engineers, U. S. A.,
President Missouri River Commission.

SURVEYS.

The authority of the Secretary of War for the expenditure of the $15,000 appropriad by act of Congress approved July 5, 1884, for "survey of the Missouri River ove the Missouri Falls, at Fort Benton," was given June 30, 1890, and preparations r the above survey were at once begun. Assistant Engineer G. A. Marr was placed charge of the field work, and, with the greater portion of his party, reached Gallatin, Mont., July 13.

The work to be done was to make a complete survey of the Missouri River, iniding secondary triangulation, topography, hydrography, and the establishment permanent bench-marks from the Three Forks (near Gallatin), where the Misuri is formed by the confluence of the Jefferson, Madison, and Gallatin rivers, to rt Benton, Mont., excepting such portions of the work as were included in the sury made in 1880 from Stubbs Ferry to Sun River, by Capt. Edward Maguire, Corps Engineers. The river distance to be covered was about 256 miles. Of this, about

131 miles were between Stubbs Ferry and Sun River, on which portion the topography and hydrography were to be omitted.

Two quarter-boat hulls were constructed at Gallatin by the party, in accordance with plans prepared at this office. Upon these, tents, made to order at St. Louis, were set up. The boats answered their purpose admirably, being comfortable, of light draft, and comparatively inexpensive. The arrangement is strongly to be recommended for similar work.

The field work of the survey began at the same time with the construction of the quarter boats. A base line 4,800 feet long was measured near Gallatin three times, with good results. Observations for azimuth at the Gallatin base were made on four nights. Twenty sets of observations were made for approximate latitude.

On reaching Great Falls, 41 miles above Fort Benton, the quarter boats were abandoned and the work carried on from camps, the quarter boat tents being used to shelter the party. Fort Benton was reached December 19, and the season's work connected with that which had previously been done from Fort Benton down.

The instruments used for the secondary triangulation were the Troughton and Simms No. 2, 10-inch, theodolite, and the Gambey No. 1, 10-inch, of the Mississippi River Commission. The latter instrument was, however, used for only two stations.

Full details of the season's work, as well as of the reduction in the office, both of this work and of his secondary triangulation work of 1889, will be found in Mr. Marr's report (Appendix A 2).

At the beginning of the fiscal year a survey party under Assistant Engineer O. B. Wheeler had begun work near Sioux City, Iowa, with a view to closing the gap in the secondary triangulation between Sioux City, at which point the work of 1889 had terminated, and Fort Leavenworth, Kans., a river distance of 385 miles. From Fort Benton to Sioux City, and from Fort Leavenworth to the mouth of the river, the triangulation had been completed in previous years. Locations for the stations between Sioux City and Fort Leavenworth had also been selected by a reconnoitering party in the fall of 1888, and most of the lines of observation were cleared during the following winter.

The two quarter boats, Nos. 5 and 6, that had been used in 1889 by Assistant Wheeler above Bismarck, N. Dak., were employed for the transportation of the party.

A base line 2¼ miles in length was measured near Blair, Nebr., on two successive evenings, the results differing only 0.08 of an inch. Between Sioux City and Blair the work had depended on the measurement in 1889 of the Running Water base, 135 miles above Sioux City. Azimuth observations were made on four nights for the Blair base, the first night's work having been rejected on account of unfavorable conditions.

The instruments used were the Troughton & Simms non-repeating 10-inch theodolite No. 1 and their 12-inch repeating theodolite, which, however, was used as a nonrepeater.

The party reached Fort Leavenworth October 22, having completed the field work; and the quarter boats used were floated down to winter quarters at the Quindaro boat yard.

Full details of the season's work will be found in Mr. Wheeler's report (Appendix A 3); also of the office reduction of this work, and of the secondary triangulation work of 1889 between Trover Point, Mont., and Bismarck, N. Dak.

The secondary triangulation is now completed over the whole length of the river. Tables giving the results of the secondary triangulation of 1885 from Fort Benton to Trover Point were published in the Commission's annual report for 1886; but the latitudes and longitudes were stated to be approximate, as they depended only on an approximate determination of the latitude and longitude of the flag-staff at Fort Benton, made in 1874 by the Northern Boundary Survey. The work having now been brought down to connect with that of 1886–'87, which was based on the latitude and longitude of the Morrison Observatory at Glasgow, Mo., the above results of 1885 have been corrected so as to depend on the Glasgow determination, and are published herewith as corrected (Appendix A 4), together with plats of the triangulation and descriptions of stations. Final results of the secondary triangulation from Three Forks to Fort Benton, and from Trover Point to Fort Leavenworth, a likewise published in the same appendix, with plats of the triangulation and d scriptions of stations. Tables of bases and of azimuths are also included. The r sults of the secondary triangulation from Fort Leavenworth to the mouth, havi been published as final in the Commission's annual report for 1887, are not repı lished. I take pleasure in acknowledging the very valuable services of Assistaı Wheeler and Marr, under whose immediate direction the whole of this importa work of secondary triangulation has been carried out.

The topographical party under charge of Lieutenant Chittenden, which beg work at Coal Banks, Montana, in May, 1890—the distance from Fort Benton to C Banks, 40 miles, having been covered in 1889—continued work through the seas

and at its close had reached Wolf Point, Mont., 395 miles below Fort Benton. Shortly after their return to the Omaha office the work was transferred to Capt. Chas. F. Powell, Corps of Engineers, under whose direction the platting of the field notes has since continued. The topographical survey of the river has thus far covered the portion between Three Forks and Wolf Point, 651 miles, and between Pierre, S. Dak., and the mouth, 1,171 miles, leaving a gap of about 700 miles between Wolf Point and Pierre.

Soon after the passage of the appropriation act of September 19, 1890, the Commission decided on making a new shore-line survey of the river from Sioux City to the mouth. Since the topographical survey of 1878 and 1879 was made, numerous and important changes in shore line have occurred; so that the published maps of that survey have become quite unreliable as to the present shore line. With a view to completing the work before the river should be closed by ice, the division engineers were directed to organize parties as quickly as possible and make the proposed survey between the limits of their respective divisions. In this way four parties were at once put in the field, two parties being required for the Kansas City division. Two additional parties were afterward made up, mostly from the parties on the Omaha and St. Joseph divisions—who had been the first to complete their work—in order to assure the completion of work on the Kansas City division before the close of navigation. The whole distance from Sioux City to the mouth, 803 miles, excepting a few reaches on which recent special surveys supplied the desired information, was covered in about 15 weeks. The field notes of the several parties were afterward platted in the offices of their respective divisions, and the maps—27 in all—sent to this office. The large amount of topographical information in possession of this office, and derived from the survey of 1878–'79 and from special surveys in recent years, is being, so far as applicable, transferred to these maps. Further details regarding the shore-line survey are given in the reports of the Division Engineers (Appendices A 5, A 6, and A 7).

Special topographical surveys were made during the year at the following localities:

- Harbor at Omaha, Nebr.
- From Miami, Mo., to 3 miles below Grand River.
- Between Kansas City, Mo., and Wellington, Mo., examination of railroad dikes.
- Kansas River at three bridge crossings, Kansas City, Kans.
- From mouth of Kansas River to Hannibal and St. Joseph Railroad Bridge, Kansas City, Mo.
- Reef at Sibley Bridge, Mo.
- Between Bee Creek, Mo., and Fort Leavenworth Bridge, Missouri and Kansas.
- Vicinity of mouth of Osage River, Mo.

PERMANENT LEVEL BENCH-MARKS.

During the year the system of permanent bench-marks in lines adopted by the Commission has been extended from near Fort Leavenworth, Kans., to Sioux City, Iowa, a distance of 384 miles. The field party, under Assistant Engineer D. W. Wellman, began work at Sioux City July 3, 1890, and ended at Fort Leavenworth November 4. The party was subdivided into a locating party and a level party, each party having one quarter boat for its transportation—quarter boats Nos. 7 and 8, which had been used during the previous year on secondary triangulation above Sioux City. On account of the great width of the valley between Sioux City and Omaha, and the shifting character of the river in this portion, necessitating unusual length of lines, the level party as at first organized was unable to make as rapid progress as the locating party. For this reason an additional level was added August 1. The secondary triangulation party was in advance of the bench-mark party throughout the whole distance covered, and the bench-mark lines were in nearly every case connected with the triangulation.

As stated in last year's annual report the bench-mark lines had previously been put in force from Iowa Point, Kans., to Atchison, Kans., a distance of 78 miles, but had not been connected with the triangulation. This connection was made by Assistant Wellman's party. Search was made also for many of the bench-marks of 1880 and 1881 on this portion of the river, and developed the fact that all of those above Omaha had disappeared or been rendered unreliable; below Omaha, however, a considerable number of them remain in good condition. The party on reaching Fort Leavenworth connected their work with the system previously established between that point and the mouth of the river. The two quarter boats were then floated down to the Quindaro boatyard, and left in care of a watchman. Full details of the season's work, with tables giving descriptions and elevations of the bench-marks established by the party, will be found in Mr. Wellman's report (Appendix A 8).

The topographical party under Lieutenant Chittenden, working down from Coal Banks, Montana, extended from Trover Point, Montana, to Wolf Point, Mont., 157 miles, the bench-mark system that had previously been put in from Fort Benton to Trover Point.

By the work of these two parties 541 miles of river were covered during the season. Six hundred and fifty-seven had been covered in previous years, so that the system now extends along 1,198 miles of river. There still remains a gap of about 1,050 miles between Wolfpoint and Sioux City.

In connection with the survey made last season by Assistant Marr from Three Forks, Montana, to Fort Benton, 256 miles, a series of permanent bench-marks were established and connected by check levels. As the region covered by this survey is for the most part mountainous and the bed of the river stable, it was not considered advisable to put in the usual lines of bench-marks across the river valley, this system being designed only for alluvial valleys in which the position of the river is liable to frequent changes. In most cases, however, it was found advantageous to use the form of bench-mark stone and pipe adopted by the Commission for the alluvial section. A table giving descriptions and elevations of these bench-marks is included in Mr. Marr's report on the survey.

GAUGES AND PHYSICAL DATA.

At the beginning of the fiscal year twenty-three gauges were maintained by the Commission. Three new gauges were established early in the year above Sioux City, but their maintenance has now been transferred to Captain Powell. During the winter the gauges at White Cloud, Kans., St. Joseph pump-house, Missouri, and Randolph, Mo., were discontinued, as being in close proximity to other gauges more favorably located. The gauges mentioned were not discontinued, however, until the slope at various stages had been carefully determined between them and the nearest gauge. As the Commission had maintained but one gauge below the mouth of the two important tributaries, the Osage and Gasconade rivers, and as this gauge was 80 miles below the lower of these tributaries, a gauge was established in May, 1891, at Cole Creek, Missouri, about 2¼ miles below the mouth of the Gasconade and 3½ miles above Hermann, Mo. At the same time a gauge was established in the same location as the Signal Service at Hermann, and will be maintained until the slope at various stages between it and the Cole Creek gauge has been determined.

All the Commission's gauges are read twice daily and the results sent to this office on weekly gauge-cards. The readings are then platted on hydrographs, by which means any serious errors are readily detected.

The gauges in each division are inspected and tested monthly by the respective division engineers and reports of the inspections forwarded to this office.

During the year a tabulation of the mean daily stages of the river between the mouth and Sioux City, Iowa, for the years 1886–1889 has been printed in pamphlet form.

A more complete description of the gauge work during the year, as well as plans showing the forms of gauges in use, will be found in the report of Assistant Engineer A. H. Blaisdell (Appendix A 9). Accompanying this report are also given tables and drawings showing the mean daily stage and discharge of the Missouri River for 12 years, 1879–1890, at St. Charles, Kansas City, and Sioux City, also mean monthly stage and discharge for the same period and the same points, showing also the annual means; also total discharge for the same period and localities.

Assistant Engineer James A. Seddon has been engaged during a part of the year in a study of the physical data in the possession of this office, during which time he has completed the first general study of the Missouri River discharge and gauge data. In his report on this work (Appendix A 10) he gives the method followed in the investigation, and the results obtained—the equivalent gauge relations from Sioux City to St. Charles; a tabulation of the standard discharge curves at Sioux City, Kansas City, and St. Charles; with a plate showing all the discharge observations at those points, and the mean curves determined for them.

Following this study, he was engaged in determining the mean discharges from 1879 to 1890 at Sioux City, Kansas City, and St. Charles, to accompany the mean gauge readings made up for those points (see Appendix A 9). The method followed consisted in scaling, on standard curves, discharges for each day, as a first approximation, and then applying at times a further correction to these values, from a comparison of the variation in volume, from point to point down the river; from these corrected values the means were made up.

He is now engaged in a more careful study of gauge relations, and the conclusions that may be reached from them.

COMMERCIAL STATISTICS.

An effort has been made to obtain as complete statistics as possible of the amount of commerce on the Missouri River between Sioux City and the mouth, for the calendar year 1890.

Lists of the steamers enrolled at the custom-houses at St. Louis, Mo., Kansas City, Mo., St. Joseph, Mo., and Omaha, Nebr., were first obtained from the surveyors of customs at those ports. The lists included the names and addresses of the owners, and to each of these a circular was sent asking the amount of business done by his boat during the year. The replies to these circulars, while usually satisfactory, were not always sufficiently definite, and in such cases the owners were visited in person. In a number of cases the boats no longer ply on the Missouri, and it was impossible, the time being limited, to reach the owners; and in many other cases the figures given are merely estimates, as the owners had no detailed record of their business. The results obtained are appended (Appendix A 1).

ESTIMATES.

Office and traveling expenses and salaries of Commission	$20,000
Surveys and observations	50,000
Physical data and publications	20,000
Gauges	10,000
Total	100,000

APPENDIX A 1.

REPORT ON THE COMMERCE ON MISSOURI RIVER DURING YEAR 1891.

OFFICE MISSOURI RIVER COMMISSION,
St. Louis, Mo., June 30, 1891.

SIR; I have the honor to submit the following report on the commerce of the Missouri River between its mouth and Sioux City, Iowa, during the calendar year 1890:

Following the same method as was employed last year, lists were first obtained from the surveyors of customs at St. Louis, Mo., Kansas City, Mo., St. Joseph, Mo., and Omaha, Nebr., giving the names of all steamboats enrolled at these points in 1890, and believed to be plying on the Missouri River in that year; giving also the names and addresses of the owners, and various detailed information regarding the boats, all of which is included in the tables accompanying this report. A circular was then sent to each steamboat owner, requesting answers to certain questions concerning the business done by his boat during the year. To most of these circulars replies were received, but were frequently so indefinite that considerable further correspondence became necessary, and, in a number of instances, personal investigation was required.

There are many lines of short trade on the Missouri where small steamers ply in the interests of the railroads, and this trade in the aggregate is large. It is also very difficult to obtain, and a personal visit to the boat owners does not always result in securing more than a rough estimate of the amount actually carried, as frequently no detailed records of the boat's business are kept.

Some cases were discovered where a steamboat having a license to ply on the "Mississippi River and tributaries," but not enrolled at the custom-house at St. Louis or any of the Missouri River ports, came into the river during the grain-shipping season, made a few trips, and, when the trade slackened, left for a distant trade where communication with her was practically impossible. A few of the steamboats in the accompanying enrolled lists have also left the Missouri River for some distant trade.

The totals obtained can, therefore, on account of unavoidable incompleteness and the frequent necessity of estimating, only be regarded as the closest practicable approximation.

These totals are for the amount carried or towed by steamboats in 1890 between Sioux City and the mouth, including 4,000 tons lumber rafted:

Tons of freight	560,557
Number of passengers	284,000

The freight consisted mainly of grain, sand, live stock, lumber, miscellaneous farm produce, and general merchandise.

The totals for the entire river for 1889 were:

Tons of freight	865,493
Number of passengers	332,218

The falling off in tons of freight carried is greater than can be explained by the fact that the totals for 1890 do not include the commerce above Sioux City. This decrease appears to be due chiefly to the extraordinary stagnation in building enterprises and business of all kinds at Kansas City, and to the building of ponton bridges at a number of points on the river, thereby diminishing the local trade by water. The decrease below Sioux City was, it should be said, altogether in commerce of a very local character; while the long-distance trade showed quite an encouraging increase.

The following table shows the number and registered tonnage of Missouri River steamboats enrolled at St. Louis and Missouri River ports below Sioux City for the years 1889 and 1890:

Enrolled at—	1890.		1889.	
	No.	*Tons.*	*No.*	*Tons.*
St. Louis, Mo	18	1,840.61	16	1,812.66
Kansas City, Mo	17	1,270.33	15	1,626.26
St. Joseph, Mo	5	277.62	5	277.62
Omaha, Nebr	10	504.72	13	1,329.55
Total	50	3,893.28	49	5,046.09

The steamers *State of Kansas* and *State of Missouri*, built in the summer of 1890 for the Kansas City and Missouri River Transportation Company, being enrolled at Louisville, Ky. (licensed to ply on the Mississippi River and tributaries), are not included in the above table. As they were built for the Missouri River trade, and one of them was engaged in that trade during the latter part of the year, their tonnage—1,130 tons each—should be included in the total for 1890, making it 6,153.28 tons, and making the total number of steamboats 52.

The steamboats engaged in Missouri River trade are employed as packets, in short-trip coasting trade, as towboats, as excursion boats, or as ferryboats. Nearly all of them are at different times employed for a variety of purposes.

The rates of insurance on the river, both for hulls and cargoes, remained through 1890 the same as for the latter half of 1889. These rates are so high as to be almost prohibitory.

NEW LINES OF TRANSPORTATION ESTABLISHED DURING THE FISCAL YEAR 1890-'91.

The packet line between St. Louis and Kansas City, 404 miles, owned by the Kansas City and St. Louis Transportation Company, was fully described in the Commission's last annual report (Annual Report Chief of Engineers, page 3371). The first boat of this line to be completed, the *A. L. Mason*, made her first trip in July, 1890. The *State of Kansas* began running in the following month. The *State of Missouri* has not yet entered the Missouri River trade. I am informed that the amount of business done by this line is steadily increasing.

A small steamer, the *Randall*, began running in the spring of 1891 as a triweekly packet between St. Louis and St. Charles, 45 miles. Her measured tonnage is 44.49.

Two small boats have been built for the short-distance coasting trade, the *St. Elmo* and the *Jumbo*, the former plying between De Witt, Mo., and near landings, and the latter in the vicinity of Hermann, Mo. A larger boat, the *Gasconade*, is nearly completed at Hermann, and is to be employed in a similar trade on the Missouri and Gasconade rivers, in connection with the Missouri Pacific Railroad at Hermann.

Such particulars as could be obtained in regard to the new boats are given in the following table:

Name.	Dimensions.			Tonnage.	Owner.
	Length.	Breadth.	Depth.		
	Feet.	*Feet.*	*Feet.*		
State of Kansas*	252	52	6	†1,130	Kansas City and Missouri River Transportation Company.
State of Missouri	252	52	6	†1,130	Do.
Randall	92	19	3	†44.49	F. L. Labarge, St. Charles, Mo.
St. Elmo	57	17.4	4.1	†25	S. B. Casebolt, De Witt, Mo.
Gasconade	107	22	3.3	†90	Hermann Ferry and Packet Company.
Jumbo (gasoline)	57.5	16	2.75	†25	Honig Brothers, Hermann, Mo.

* Full measurements of steamer *A. L. Mason* are given in list of steamers enrolled at St. Louis.
† Estimated.

Very respectfully, your obedient servant,

JAMES C. SANFORD,
First Lieut. of Engineers, Secretary.

Lieut. Col. CHARLES R. SUTER,
Corps of Engineers, U. S. A.,
President Missouri River Commission.

TABLE 1.—*List of steamers plying on the Missouri River, in the district of New Orleans, enrolled at the port of St. Louis, Mo., during the year 1890.*

Name.	Where built.	Year.	Date of last inspection.	Dimensions.			Total tonnage.
				Length.	Width.	Depth.	
			1890.	*Feet.*	*Feet.*	*Feet.*	*Tons.*
Albert S. Willis	Louisville, Ky	1885	Mar. 19	153.1	26.5	3.6	132.99
Alice Blair	Osceola, Mo	1890	June 10	130	25	4	119.96
A. W. Ewing	Osage City, Mo	1878	Apr. 28				4
Benton	Pittsburg, Pa	1875	Aug. 14	197	33	5	394.08
Black Diamond	Portland, Mo	1886	May 12	72.5	14.4	2.3	18.40
Commodore	New Haven, Mo	1890	June 7	97	23.2	3.2	86.45
Fawn	Hermann, Mo	1880	Apr. 28	91.8	19.1	3.4	73
Dan B. Hurlbut	Warsaw, Mo	1881	June 1	62.6	11	2.4	12.92
Frederick	Tuscumbia, Mo	1883	Apr. 28	96.4	14.3	3	82.51
Helena	Pittsburg, Pa	1878	June 28	194	33	4.5	352.31
H. W. Longfellow	Lake Minnetonka, Minn	1881	Aug. 28	76	14.5	3.7	46.89
John L. Ferguson	Grafton, Ill	1876	Oct. 27	111.6	26.6	3.6	79.81
John R. Hugo	Evansville, Ind	1879	Apr. 28	127	20	3	136.88
May Bryan	Jeffersonville, Ind	1875	Nov. 25	115	28	4.5	97.40
Pin Oak	Hermann, Mo	1888	Apr. 28	95	17.5	2.2	43.05
Pinta	Louisiana, Mo	1890	June 13	43.6	8.7	3	8.62
Royal	Hermann, Mo	1884	Apr. 28	86.6	24	3	44.82
Statie Fisher	Jeffersonville, Ind	1875	Apr. 11	122	28.8	4.6	106.52

TABLE 1.—*List of steamers plying on the Missouri River, etc.*—Continued.

Name.	State-rooms.	Berths.	Passengers. Permitted to carry.	Passengers. First cabin.	Passengers. Steerage or deck.	Engines. Number.	Engines. Diameter of cylinder.	Engines. Stroke.
							Inches.	*Feet.*
Albert S. Willis						2	16½	6
Alice Blair	12	24	36	16	20	2	10	4
A. W. Ewing			8		8	1	6	¾
Benton	18	36	66	30	36	2	15½	5
Black Diamond	3	6	16	6	10	2	6	3
Commodore			30		30	2	10	4
Fawn	3		50	20	30	2	8	2
Dan B. Hurlbut								
Frederick	4	13	28	13	15	2	7	2½
Helena	16	32	62	30	32	2	13½	5½
H. W. Longfellow			85		85	2	8	¾
John L. Ferguson			20		20	2	11	4
John R. Hugo	5	9	40	10	30	2	8	3
May Bryan			50		50	1	16	5
Pin Oak			20		20	2	8	2½
Pinta			20		20	2	5	¾
Royal			20		20	2	8	2½
Statie Fisher			25		25	1	16½	5

Name.	Boilers. Number.	Boilers. Length.	Boilers. Diameter.	Boilers. Flues. Number.	Boilers. Flues. Diameter.	Boilers. Steel or iron.	Boilers. When built.	Boilers. Steam pressure allowed.	Licensed to run on—	Name and address of sole or managing owners.
		Ft.	*In.*		*In.*			*Lbs.*		
Albert S. Willis	3	22	47	18	9	Steel.	1881	145	Mississippi and tributary rivers.	St. Louis and Mississippi River Packet Co., St. Louis, Mo.
Alice Blair	1	20	56	14	6	Steel.	1890	129	....do	R. D. Blair, Osceola, Mo.
A. W. Ewing	1	3	40			Steel.	1885	125	....do	C. C. Turner, St. Louis, Mo.
Benton	3	24	38	6	13½	Iron.	1875	125	....do	Robert Roehrig, Washington, Mo.
Black Diamond	1	14	30			Steel.	1886	130	....do	L. C. Lohman, Jefferson City, Mo.
Commodore	1	20	44	6	2–12 4–6	Steel.	1890	153	....do	S. H. Schleef, New Haven, Mo.
Fawn	1	14	42	4	2–10 2–12	Iron.	1877	110	....do	W. L. Heckman, Hermann, Mo.
Dan B. Hurlbut									....do	Henry Castrop, Westphalia, Mo.
Frederick	1	14	36	6	6	Iron.	1883	150	....do	Henry Castrop, Tuscumbia, Mo.
Helena	2	24	42	10	10	Steel.	1878	159	....do	A. S. Bryan, Washington, Mo.
H. W. Longfellow	1	12½	48	1	28	Iron.	1882	135	....do	Jefford Bros., Kingston Mines, Peoria Co., Ill.
John L. Ferguson	1	16	42			Iron.	1864	91	....do	Austin Owen, St. Charles, Mo.
John R. Hugo	1	16	42	5	10	Iron.	1882	119	....do	R. M. Marshall, Tuscumbia, Mo.
May Bryan	1	22	44	5	2–12 3–10	Iron.	1875	113	Missouri River, St. Charles to 10 miles above Hermann.	Washington Ferry Co., Washington, Mo.
Pin Oak	1	17	40			Steel.	1888	125	Missouri River and tributaries.	W. L. Heckman, Hermann, Mo.
Pinta	1	6	42	1	20	Steel.	1890	120	Mississippi and tributary rivers.	W. H. Boyd, Louisiana, Mo.
Royal	1	12	36	5	7	Steel.	1884	125	....do	W. L. Heckman, Hermann, Mo.
Statie Fisher	1	22	42	5	10	Steel.	1875	140	Missouri River, 50 miles above and below Jefferson City.	Capital City Ferry Co., Jefferson City, Mo.

TABLE 2.—*List of steamers plying on the Missouri River, in the district of New Orleans, enrolled at the port of Kansas City during the year 1890.*

Name.	Where built.	Year.	Date of last inspection.	Dimensions. Length.	Width.	Depth.	Total tonnage.
			1890.	*Feet.*	*Feet.*	*Feet.*	*Tons.*
Aggie	Manchester, Ohio	1875	May 23	92.4	20.4	3.1	88.51
A. L. Mason	Madison, Ind	1890	June 20	252.0	52.0	6.0	1,130.34
Annie Cade	Leavenworth, Kans	1879	May 23	127.5	32.0	4.5	178.32
Annie Lewis	Glasgow, Mo	1879	May 24	93.4	27.0	2.0	81.14
Argentine	Kansas City, Mo	1886	May 23	124.2	19.6	2.8	21.86
Carrie	St. Louis, Mo	1881	May 23	75.0	13.0	2.0	29.82
City of Brunswick	Brunswick, Mo	1890	Aug. 11	87.9	19.6	3.9	77.01
Edna	Boonville, Mo	1887	May 23	102.0	21.5	4.7	88.35
Harry Clyde	New Frankfort, Mo	1889	Nov. 20	60.9	23.3	3.3	23.79
Jennie Gilchrist	St. Claire, Iowa	1871	May 23	100.5	18.5	3.8	74.40
Jos. L. Stevens	Jeffersonville, Ind	1887	May 23	103.0	29.4	4.2	85.95
Krata	St. Louis, Mo	1888	May 14				5.00
Lillie Maud	De Witt, Mo	1887	May 14	58.3	11.8	3.5	15.25
Mattie Lee	Grafton, Ill	1881	May 14	110.0	28.0	4.0	104.81
Plow Boy	Sioux City, Iowa	1884	May 23	70.0	18.0	3.0	29.22
Roy Lynds	Jeffersonville, Ind	1887	May 23	87.0	25.0	3.6	64.09
Willie Cade	Metropolis, Ill	1881	May 23	131.6	31.0	4.8	177.47

Name.	State-rooms.	Berths.	Passengers. Permitted to carry.	First cabin.	Steerage or deck.	Engines. Number.	Diameter of cylinder.	Stroke.
							Inches.	*Feet.*
Aggie						2	12	3½
A. L. Mason	11	22	100	50	50	2	20	7
Annie Cade						1	20½	5½
Annie Lewis						1	15½	5
Argentine						1	8	1
Carrie						2	6	2
City of Brunswick	4	12	25	8	17	2	8	3
Edna	6	12	33	8	25	2	8	3½
Harry Clyde		1			20	2	6	2
Jennie Gilchrist			8		8	2	12	3
Jos. L. Stevens						2	10	3½
Krata						2	5½	[illegible]
Lillie Maud					15	1	6	1
Mattie Lee	2	4			30	1	16	4½
Plow Boy					10	2	8	2
Roy Lynds						2	9	3
Willie Cade						1	20	5

TABLE 4.—*List of steamers plying on the Missouri River, etc.*—Continued.

Name.	State-rooms.	Berths.	Passengers. Permitted to carry.	Passengers. First cabin.	Passengers. Steerage or deck.	Engines. Number.	Engines. Diameter of cylinder.	Engines. Stroke.
							Inches.	*Feet.*
Abner O'Neal	16	34	46	34	12	2	14	5
Andrew S. Bennett			75		75	2	11.5	4½
Capitola Butt			20		20	2	11	3½
Josie L. K			30		30	1	6	½
Last Chance			32	2	30	2	11	3
Liberty			10		10	1	5	$\frac{7}{12}$
Little Maud						2	10.5	3
Mary E. Bennett			50		50	1	7.5	1½
Queen No. 2						1	7.5	¾
Sioux			15		15	1	4.5	$\frac{5}{12}$

Name.	Boilers. Number.	Boilers. Length.	Boilers. Diameter.	Boilers. Flues. Number.	Boilers. Flues. Diameter.	Boilers. Steel or iron.	Boilers. When built.	Boilers. Steam pressure allowed.	Licensed to run on—	Name and address of sole or managing owner.
		Ft.	*In.*		*In.*			*Lbs.*		
Abner O'Neal	2	20	42	12	8	Steel.	1884	170	Missouri River, between Omaha and Fort Benton.	R. A. Talbott, Mandan, N. Dak.
Andrew S. Bennett	1	22	48	6	2–14 / 4–7½	Steel.	1883	146	Mississippi and tributary rivers.	D. Ayers, Ponca, Dixon Co., Nebr.
Capitola Butt	1	20	46	10	8	Steel.	1885	145	....do	Oliver F. and Wm. H. Butt, Nebraska City, Nebr.
Josie L. K	1	5½	40			Iron.	1880	125	....do	A. Larson and H. Drange, Yankton, S. Dak.
Last Chance	1	18	42			Iron.	1870	83	....do	M. K. King, Chamberlain, S. Dak.
Liberty	1	3¾	36	*86	1½ / 16	Steel.	1887	115	Missouri and tributary rivers.	E. E. French, Omaha, Nebr.
Little Maud	1	26	40			Steel.	1889	156	Missouri River and tributaries, between Running Water, S. Dak., and Niobrara, Nebr., as ferry-boat, and between Running Water and Fort Randall as freight boat.	Jos. Leach, Sioux City, Iowa.
Mary E. Bennett	1	6¼	42			Steel.	1888	120	Mississippi and tributary rivers.	Wm. Luther, Covington, Nebr.
Queen No. 2	1	7½	30			Iron.	1877	110	Missouri River at ferry crossings.	B. F. Hull & Son, Decatur, Nebr.
Sioux	1	4	26	*33	2 / 17	Steel.	1888	100	Sioux River, between mouth and head of navigation.	Sioux City and Highland Park R. R. Co.

*Tubes.

APPENDIX A 2.

ANNUAL REPORT OF MR. G. A. MARR, ASSISTANT ENGINEER, 1891.

OFFICE MISSOURI RIVER COMMISSION,
St. Louis, Mo., July 1, 1891.

SIR: I have the honor to submit the following report for field and office work during the fiscal year ending June 30, 1891.

FIELD WORK IN MONTANA.

A complete survey, consisting of secondary triangulation, topography, hydrography, and checked levels, was made from Three Forks, Mont., to Fort Benton, Mont., with the exception of topography and hydrography from Stubbs Ferry to Sun River, which were made under the direction of Capt. E. Maguire in 1880.

Received orders on July 5 to proceed to Helena, Mont., to procure outfit, and then to Gallatin, Mont., where the work was to commence. After procuring lumber for two quarter-boat hulls, and outfit for party, and setting a gauge at Stubbs Ferry, I reached Gallatin, Mont., on July 13, in the evening. On the morning of the 14th, Mr. R. L. Hazen, of Sioux City, Iowa, was on hand to build the quarter-boat hulls, and to act as mate during the season. As the greatest part of the lumber had arrived, the work of constructing the boats was commenced, a base line of 4,800 feet selected, stadia boards prepared, and on July 19 the topography and levels were commenced, and the base line that had been staked out was measured three times after 4:55 p. m. A complete quadrilateral system of secondary triangulation was carried down from Gallatin Base, at Three Forks, to connect at Fort Benton with the triangulation of 1885. In reconnoitering for this system, the usual conditions for primary work were maintained throughout, with no angle in the direct system of triangles less than 30 degrees. The observations for angles were made by Assistant Engineer O. H. B. Turner with the Throughton and Simms No. 2 10-inch theodolite, except at two stations, which were occupied by Assistant Engineer T. C. Thomas with Gambey No. 1, 10-inch theodolite. The observations for angles were excellent, there being 78 stations occupied, and over 90 per cent. of the triangles closed within the primary limit of 3-second closure, and all well within the secondary limit of 6 seconds. Heavy snowstorms in the mountains during the month of October made it difficult to recognize targets, hence the per cent. of good closure was somewhat reduced on that section of work.

A base line was selected at Gallatin, 4,800 feet in length, on the level bottom land and was measured three times, the first only as practice and not used, but is reduced to show that even with inexperienced help and fluctuating temperature a very close approximation can be made. Standard tape No. III, of the Missouri River Commission, was used in the measurement, and the two standard thermometers, Nos. 5,100 and 5,108, made by Green of New York. Full reports on these standards have been made in the Annual Reports of the Chief of Engineers for base apparatus in 1889 and for thermometers in 1890.

Observations for azimuth were made at South Base, near Gallatin, on four nights, obtaining twenty-six results on Polaris and fifty-three observations on time stars. There were also twenty sets of observations for the approximate latitude.

The shore line and topography were done with use of stadia, checking the work by tertiary triangulation points at frequent intervals. The sloughs and side channels were generally located by independent lines, the same as the main channel, and in some of the more important side channels soundings were taken. Soundings were made from a skiff with sounding pole graduated to tenths of a foot, and a lead line was carried along in the skiff for getting the depth in any deep pools.

Careful checked levels were run over the whole section of river from Three Forks to Fort Benton, and for nearly the whole distance by two independent observers. The usual permanent bench-marks were established from 3 to 5 miles apart along the banks of the river. The U. S. Geological Survey had established bench-marks and gauges at Toston, Canyon Ferry, and Craig for discharge measurements, and these points were all connected within our systems of checked levels. Data was obtained from the office of the Northern Pacific Railroad in St. Paul, Minn., for the elevation above sea level of points at Gallatin, from which our system of levels were commenced, and hence our elevations as reduced in the field refer to sea level as obtained from the Northern Pacific Railroad, their data depending upon the mean level of Lake Superior, taken as 602 feet above the mean level of the Atlantic Ocean.

Water surfaces were taken frequently to give the fall in the river, gauge readings being taken daily at six different points along the river, one gauge being that at Fort Benton, established on the bridge at that place by Lieut. H. M. Chittenden, and set

with its zero at low water of 1889. The gauge at Toston, Mont., was set by the U. S. Geological Survey, and its zero was over a foot below the low water of 1889, as derived from a comparison of the six gauges during a quiet stage of water. The four gauges established during the field work of 1890 were all set with their zeros as near low water as could be estimated at the time of setting.

Five approximate discharge measurements were made, three on the three branches at the head of the river, and two on the main river, one near the head and the other at Canyon Ferry. These were hastily made, and only intended to give a general idea of the amount of water in the river, the stage being quite low and favorable at the time.

Comparison of gauges.

Date.	Gallatin.	Gallaher.	Toston.	Stubbs.	Craig.	Great Falls.	Fort Benton.
1890.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Nov. 1	0.47	0.43	1.8	0.7	0.35	0.93	0.72
2	0.47	0.44	1.8	0.7	0.35	0.94	0.75
3	0.47	0.43	1.85	0.7	0.35	0.94	0.75
4	0.48	0.42	1.9	0.7	0.37	0.92	0.75
5	0.47	0.45	1.9	0.7	0.37	0.95	0.75
6	0.47	0.45	1.9	0.75	0.37	0.99	0.75
Means	0.47	0.44	1.86	0.71	0.36	0.94	0.75
Lowest water.							
Oct. 1	0.36	0.05	1.55	0.38	0.00	0.88	0.85

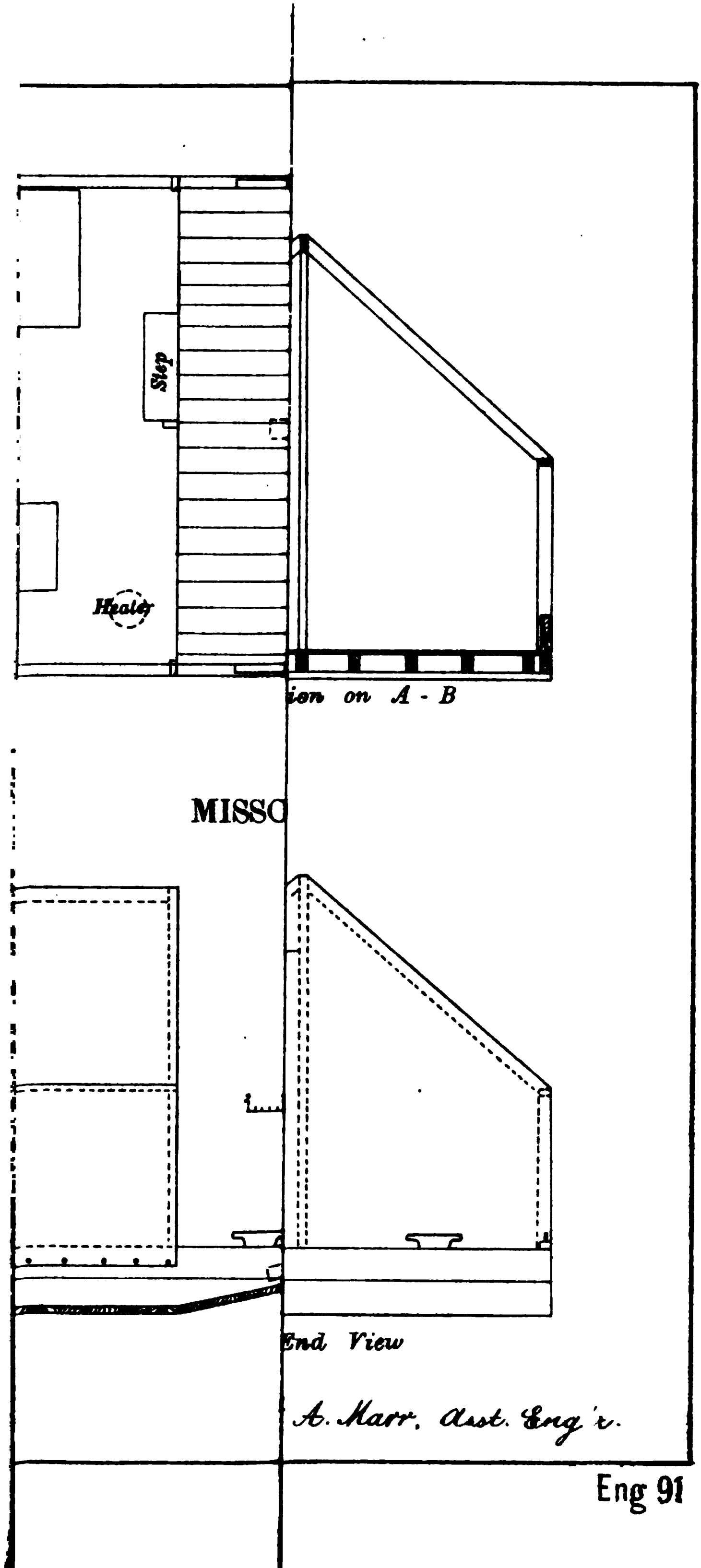
The gauge at Craig was not read in connection with the work, but a copy of the readings of that gauge was obtained for comparison. The following methods were used in deriving elevations: The levels were all run in duplicate or carefully checked by independent lines; the means of two results at checking points, from 2 to 5 miles apart were used in going ahead from that point, the limit of error between two lines in checking being 0.2 feet in 5 miles. The permanent bench-mark points were always used in checking, and occasionally a point between would be used at the end of a day's work, or otherwise.

As the use of tents on flatboats for subsisting the party in the field resulted especially from the necessity for light-draft boats on the head waters for the work of this season, drawings and plans, with a photograph * of the boats, are submitted. The hulls were 14 by 50 feet and made on the same plan as previous quarter-boat hulls, except that some of the timbers were lighter, and the gunwales only 20 inches high and perpendicular. The tent was 14 by 40 feet, with 5-foot wall. The ends were the same as for an ordinary tent, except with one foot extra lap for the door openings on account of exposure to winds. The doors and windows, as shown on the sketch, are openings of one width of canvas (29 inches), the windows 3 feet in depth, and both door and windows covered with canvas one foot wider than the openings, and the windows 6 inches deeper to give a lap of 6 inches all around. The door and window covers were all fastened securely at the top, or upper edge of the wall, and tied at the sides and bottom. The partitions are the same as ends to an ordinary tent, except that they were left open entirely to the top in the center, for the ridge pole, and at the sides for the wall supports, the center and sides having strings for fastening in place. These partitions are located, one 15 feet from the bow end of the tent and the other 16 feet from the stern end, leaving 9 feet between for kitchen. One side of the tent has three windows and a door and the other side three windows. The tent does not need ropes when used on a boat, but has the usual eyelets both at the upper edge of the wall and around the bottom.

These canvas-top quarter boats answered the purpose well, and were used from Three Forks to Great Falls, where they were abandoned on account of the falls and rapids below. From this point to Fort Benton the topography and levels were done from camps, which were moved by teams, but with great difficulty and delay, on account of the many "coulees" and gulches along the banks of the river below Great Falls.

The organization of the party for this work consisted of 1 assistant engineer in charge, 3 other assistant engineers, 6 recorders, 2 mates, 1 foreman, 2 cooks, 1 second cook, and 12 laborers, a total of 28 men. This organization carried on the work usually done by three distinct parties, which enabled the work to be done with much less outfit and expense. In the field work Assistant Engineer O. H. B. Turner had charge of the observations on the secondary triangulation and azimuth, and accomplished the

* Omitted.



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work most satisfactorily. Assistant Engineer T. C. Thomas started in charge of the checked levels, and Assistant Engineer J. L. Sanders in charge of shore line and topography; but it was soon found necessary to increase the force on the shore line and topography, and Mr. Thomas was placed in charge, Mr. Sanders still assisting. Recorder J. W. Woermann was then placed in charge of checked levels, and did the work well, being assisted part of the time by Recorder L. P, Butler, who ran an independent line between checking points. It was generally possible to keep the different kinds of work moving, so that one part would not delay another.

Mr. J. W. Woermann had a photographic camera along with the party, and some excellent views of rapids, cañons, bluffs, falls, etc., were obtained during the season.

The field work was completed at Fort Benton on December 19, and the property stored at the Government fleet just below Fort Benton; arrived at the office in St. Louis on December 25.

The following tabulation gives the amount of field work done:

Secondary triangulation stations located	76
Secondary triangulation stations put up	77
Secondary triangulation stations occupied	78
Secondary triangulation, angles measured	379
Tertiary triangulation points located	103
Public buildings and prominent points located	55
Miles of shore line and topography	249
Miles of duplicate levels	258
Miles of single levels for water surfaces	45
Water surfaces obtained	395
Lines of sounding	2,112
Discharge measurements	5
Gauges established	4
Permanent bench-marks established	53
Base line measured	1
Sets of observations for azimuth	26
Sets of observations for approximate latitudes	20
Time stars observed	53
Quarter boats built	2
Skiffs built	5

OFFICE WORK IN ST. LOUIS, MISSOURI.

At the close of the field work the last of December, Mr. Turner and Mr. Butler were retained in the office to assist in the reduction of field notes and mapping the survey. They were engaged on special computations below Sioux City, Iowa, until January 8, when the reduction of the field work was commenced. The secondary triangulation was first computed in full detail, with least square adjustment of quadrilaterals and plane coördinates of all the stations determined using the azimuth at △ Benton, and that station as origin. Then all tertiary triangulation points were located and their coördinates determined for developing the details of shore line and topography. The coördinates of all stadia points from Fort Benton to Sun River have been computed and checked by the coördinates of the tertiary triangulation points, and this part of the river has been mapped on a scale of 400 feet to an inch, requiring 7 sheets of the standard size, 6¼ feet in length, to develop the work. The details of the survey have all been platted in pencil on these sheets, and four of the maps have been finished in ink by Mr. Kossak. A printing outfit similar to that used by the Mississippi River Commission was obtained, and all the work that could be inked with type has been finished in that manner.

At several points between Stubbs Ferry and Sun River reëxaminations were made and from these surveys and such tertiary triangulation points as could be connected with quite definite points of Captain Maguire's survey of 1880, a comparison could be obtained between the coördinates of the survey of 1880 and those of this survey of 1890; and such comparisons have been made and corrections introduced, so as to reproduce the maps of the survey of 1880, with such additional notes as were obtained in this survey. Mr. C. M. Winchell has been at work reproducing these maps since May 20, and has seven sheets of the standard size completed in pencil.

The computations in the reduction of the secondary triangulation from Three Forks to Fort Benton were made in duplicate by Mr. Turner and Mr. Butler and carefully checked. There were 76 direct triangles, covered by 37 quadrilaterals, and all angles were adjusted in this system, there being 298 angles.

The corrections to the observed angles from the quadrilateral least square adjustment are shown as follows:

Between 0 and 1 second	242
Between 1 and 2 seconds	50
Between 2 and 3.2 seconds	6

The Gallatin base at Three Forks was used in computing the triangulation, and the work checked on the line △ Teton–△ Benton of the work of 1885, the slight difference in the results being distributed back through the system. In the computation for latitude, longitude, and azimuth, the data at △ Benton, as determined in 1885, was used, the computation being made by myself, and checked by closing around each triangle.

The court-house in Helena, Mont., was connected within our system of triangulation from two bases, giving a check on the work, as the latitude and longitude of this point had been determined by the U. S. Coast and Geodetic Survey. The latitudes and longitudes as finally reported for the stations of the secondary triangulation depend on the observed latitude and longitude of the Morrison observatory at Glasgow, Mo.; and in comparing at Helena, Mont., the work has been carried through about 1,600 miles axial distance along the Missouri River.

The following is a comparison of the two determinations at Helena, Mont.

	Latitude.			Longitude.		
	°	′	″	°	′	″
Court-house, U. S. Coast and Geodetic Survey	46	35	17.5	112	02	05.74
Court-house by triangulation	46	35	07.23	112	02	01.06

This gives a difference of 10.27″ in latitude and 04.68″ in longitude, the triangulation being less than the observed. As Helena is located in the Rocky Mountains, station error in the observed results may account for a part of the difference.

Final results for this triangulation from Three Forks, Mont., to Fort Benton are given in Table I, Appendix A 4, and the scheme of the system in Sketch I, Appendix A 4, the main system of triangles being shown by full lines, and the diagonals of the quadrilaterals by broken lines.

REDUCTION OF GALLATIN BASE AT THREE FORKS, MONTANA.

This reduction was made by myself and checked by Mr. Turner, and its length reduced to sea level, which was used in the computation of triangles from Three Forks to Fort Benton. The reduction is submitted and follows this report.

REDUCTION OF AZIMUTH AT THREE FORKS, MONTANA.

The computations of this work were made in duplicate by Mr. Turner and Mr. Butler and carefully checked. The mean results for four nights' work are given in "Table of Azimuths," Appendix A 4.

A full list and description of all permanent bench-marks established in 1890 from Three Forks to Fort Benton, with their elevations above sea level, are submitted, and follow the reductions of the Gallatin base. The descriptions of stations of the secondary triangulation on this section of the river are also submitted, and follow the sketches of triangulation, Appendix A 4.

REDUCTION OF SECONDARY TRIANGULATIONS FROM BISMARCK, NORTH DAKOTA, TO SIOUX CITY, IOWA.

The field work for this section of river was done in 1889, and the computations were all made in duplicate and carefully checked during the winter of 1889 and 1890. Three bases were measured, and a full report has been made on their measurement and reduction and published in the Report of the Chief of Engineers for 1890; but the reduction of triangles and the results have not been published.

TRIANGULATION FROM BISMARCK TO PIERRE.

On this section of river the system of triangulation contained 62 direct triangles, covered by 31 quadrilaterals, all the angles in the system of quadrilaterals being observed. In the 247 angles the corrections to the observed angles, as derived from the least square adjustment, lie as follows:

Between 0 and 1 second	153
Between 1 and 2 seconds	72
Between 2 and 3 seconds	19
Between 3 and 4.5 seconds	3

The final results of this triangulation are given in Table V, Appendix A 4, and the plan of the system is Sketch V, Appendix A 4.

At Bismarck, N. Dak., the U. S. Coast and Geodetic Survey made observations for latitude and longitude in 1890, and the results of their determinations have been sent to this office through the kindness of Prof. T. C. Mendenhall, superintendent. As our system of triangulation had been connected with the flagstaff of the court-house in Bismarck, and their observations referred to the same point, we are able to give the following comparison:

	Latitude.			Longitude.		
	°	′	″	°	′	″
Court-house cupola, U. S. Coast and Geodetic Survey	46	48	27.40	100	46	57.21
Court-house cupola, triangulation	46	48	26.63	100	46	59.51

The results from triangulation, as given above, depend on the observed latitude and longitude of the Morrison Observatory, at Glasgow, Mo., which is 850 miles axial distance along the system of triangulation from Bismarck.

TRIANGULATION FROM PIERRE TO RUNNING WATER.

On this section of the river there were 50 direct triangles, covered by 25 quadrilaterals, all angles in the system being observed. In the 198 angles the corrections to observed angles from least square adjustment lie as follows:

Between 0 and 1 second	111
Between 1 and 2 seconds	53
Between 2 and 3 seconds	24
Between 3 and 4.6 seconds	10

The final results for the triangulation on this section are given in Table VI, Appendix A 4, and the system of triangles on Sketch VI, Appendix A 4.

TRIANGULATION FROM RUNNING WATER TO SIOUX CITY.

The L. M. Z. computation of this part of the work of 1889 was not made until this year, when a check could be obtained at the Blair base from the work by Assistant Engineer O. B. Wheeler in 1890.

The triangulation of 1889 had all been reduced in duplicate, there being 22 direct triangles, covered by 11 quadrilaterals, all angles being observed. In the 88 angles, the corrections are shown below:

Between 0 and 1 second	48
Between 1 and 2 seconds	29
Between 2 and 3.6 seconds	11

The final results of the triangulation on this section are given in Table VII, Appendix A 4, and the scheme of triangulation on Sketch VII, Appendix A 4.

REDUCTIONS OF AZIMUTHS AT PIERRE AND RUNNING WATER.

These reductions for the work of 1889 were made by Mr. J. J. Sanders and checked by Mr. Turner, and the results at both stations are given in "Table of Azimuths," Appendix A 4.

The descriptions of stations in the secondary triangulation of 1889 from Bismarck, N. Dak., to Sioux City, Iowa, are also submitted, and follow the sketches in Appendix A 4, being given in sections corresponding to the divisions of the system of secondary triangulation.

Very respectfully, your obedient servant,

G. A. MARR,
Assistant Engineer.

First Lieut. J. C. SANFORD,
Corps of Engineers, U. S. A.

GALLATIN BASE.

Temperatures during measurements.

No. of tape.	First measurement.			Second measurement.			Third measurement.		
	July 19, 1890, p. m.	Thermometers.		July 19, 1890, p. m.	Thermometers.		July 19, 1890, p. m.	Thermometers.	
		5108.	5100.		5108.	5100.		5108.	5100.
	h. m.	°	°	h. m.	°	°	h. m.	°	°
1	4 55	78.1	77.7	6 43	75.8	75.8	7 52	73.5	73.2
2	5 05	80.2	80.0	6 46	75.0	74.6	7 55	73.2	72.8
3	....	78.4	78.4	6 49	73.8	73.6	7 58	71.3	71.4
4	5 12	76.1	76.2	6 51	73.6	73.4	8 01	70.0	69.8
5	5 15	76.1	75.8	6 53	73.9	73.6	8 03	70.4	70.0
6	5 18	75.8	75.6	6 55	73.9	73.8	8 06	69.4	69.6
7	5 22	75.5	75.3	7 00	73.0	72.8	8 09	69.0	68.3
8	5 25	75.0	74.8	7 03	72.9	72.6	8 11	68.2	67.8
9	5 27	75.0	75.5	7 05	73.3	73.6	8 13	68.3	68.7
10	5 30	75.0	75.5	7 07	73.6	73.4	8 16	68.8	69.4
11	5 32	76.0	76.1	7 10	73.9	74.0	8 18	69.4	70.0
12	5 34	75.8	75.6	7 12	73.9	73.7	8 21	69.0	69.6
13	5 36	76.4	76.4	7 15	74.0	73.6	8 23	69.2	69.2
14	5 38	76.8	76.5	7 17	73.8	73.5	8 26	69.0	69.2
15	5 41	76.5	76.6	7 19	74.0	73.6	8 29	68.9	68.5
16	5 43	76.8	76.5	7 22	73.9	73.5	8 31	68.5	68.1
Means for each thermometer		76.47	76.41	....	73.89	73.69	....	69.76	69.72
Means for each measurement		76.44		....	73.79		....	69.74	
Corrections		— 0.2		....	— 0.2		....	— 0.2	
Corrected means		76.24		....	73.59		....	69°54	

Correction for inclination (i) of tape, Gallatin base.

[$\sin i = \frac{h}{l}$. Correction $= l \times$ Ver. sin $i = l \times 2 \sin^2 \frac{1}{2} i$. $l = 300.'02398$ = length of tape No. III at 62° F.]

No. of stake.	Elevation.	Difference of elevation = h.	Log. h.	Log. sin i.	i.	Log. sin ½ i.	Log. sin² ½ i.	Log. l + log. ver. sin i = log. 2 l + log. sin² ½ i.	Corrections.
	′	′			° ′ ″				′
S. base	11.101								
1	11.067	0.034	8.53148	6.05432	0 00 24	5.76476	1.52952	4.30771	0.00000
2	7.332	3.735	0.57229	8.09513	42 48	7.79414	5.58828	8.36647	0.02325
3	5,988	1.344	0.12840	7.65124	15 24	7.35022	4.70044	7.47863	0.00301
4	4.611	1.377	0.13893	7.66177	15 46	7.36044	4.72088	7.49907	0.00316
5	5.845	1.234	0.09132	7.61416	14 08	7.31294	4.62588	7.40407	0.00254
6	5.872	0.027	8.43136	5.95420	00 18	5.63982	1.27964	4.05783	0.00000
7	4.844	1.028	0.01199	7.53483	11 46	7.23335	4.46670	7.24489	0.00176
8	3.909	0.935	9.97081	7.49365	10 42	7.19208	4.38416	7.16235	0.00145
9	3.814	0.095	8.97772	6.50056	1 06	6.20409	2.40818	5.18637	0.00002
10	4.001	0.187	9.27184	6.79468	2 08	6.49175	2.98350	5.76169	0.00006
11	4.154	0.153	9.18469	6.70753	1 46	6.40985	2.81970	5.59789	0.00004
12	2.189	1.965	0.29336	7.81620	22 30	7.51488	5.02976	7.80795	0.00643
13	3.765	1.576	0.19756	7.72040	18 04	7.41957	4.83914	7.61733	0.00414
14	1.162	2.603	0.41547	7.93831	29 50	7.63740	5.27480	8.05299	0.01130
15	2.428	1.266	0.10243	7.62527	14 30	7.82406	4.64812	7.42631	0.00267
16	0.000	2.428	0.38525	7.90809	27 50	7.60726	5.21452	7.99271	0.00983

$\frac{82.082}{17} = 4.828$ mean elevation.

Total correction for inclination = 0.06966

4,024′.760 = Elevation of zinc 16 (△ N. base) above sea level.
+4.828 = Mean elevation of Gallatin base above △ N. base.

4,029.588 = Mean elevation of Gallatin base above sea level.

Correction to reduce to sea level:

$= \frac{Ba}{N}$ **(See Lee's Tables, page 84).**

$$\begin{aligned} \text{Log. B} &= \log 4,800'.91978 = 3.6813245 \\ \text{Log. } a &= \log 4,029.588 = 3.6052607 \\ & \qquad 7.2865852 \\ \text{Log. N (at Lat. } 45^\circ 54') &= 7.3213851 \\ \text{Log. correction} &= 9.9652001 \\ \text{Correction} &= 0'.92300 \end{aligned}$$

Three measurements of Gallatin base expressed by the following equations:

(First). [16 × 300′.02398] + 0′.47235 + 0′.02000 + 0′.06966 = 4,800′.94569 Rejected in the field.
(Second.) [16 × 300′.02398] + 0′.38445 + 0′.08583 + 0′.06966 = 4,800′.92362
(Third.) [16 × 300′.02398] + 0′.25011 + 0′.21250 + 0′.06966 = 4,800′.91595
Mean of second and third measurements = 4,800′.91978.

First term is number of tapes into length of tape at 62° F.
Second term is temperature correction.
Third term is distance between end of last tape and △ N. base.
Fourth term is correction for inclination of tape.
The second member is the corrected independent result for each measurement.

The mean of two measurements = 4,800′.91978
Correction to reduce to sea level = 0′.92300

Gallatin base reduced to sea level = 4,799′.99678

Measured differences on zincs, Gallatin base.

Number of stake.	Measurements.		
	First—second.	Second—third.	First—third.
	Inch.	*Inch.*	*Inch.*
1	+0.04	+0.06	+0.10
2	+0.14	+0.12	+0.26
3	+0.23	+0.21	+0.44
4	+0.27	+0.28	+0.55
5	+0.31	+0.36	+0.67
6	+0.34	+0.44	+0.78
7	+0.40	+0.52	+0.92
8	+0.46	+0.61	+1.07
9	+0.48	+0.76	+1.24
10	+0.50	+0.86	+1.36
11	+0.51	+0.99	+1.50
12	+0.58	+1.08	+1.66
13	+0.61	+1.18	+1.79
14	+0.64	+1.26	+1.90
15	+0.72	+1.39	+2.11
16	+0.79	+1.52	+2.31

Descriptions and elevations of permanent bench-marks established along the Missouri River during the survey between Three Forks, Mont., and Fort Benton, Mont., by Assistant Engineer G. A. Marr, season 1890. Elevations are in feet above mean tide sea-level as taken from the Northern Pacific Railroad levels at Gallatin, Mont.

[The railroad levels depend on the elevation of Lake Superior as determined by the U. S. Lake Survey.]

Number.	Description.	Elevation.
1 (Three Forks)	Is located at the southwest corner of the Three Forks Hotel, Three Forks, Mont. It is inside of the hotel yard, 1½ feet from fence and 1 foot from west wall of building. Marked by the regulation stone and pipe.	4,040.158
2 (Gallatin)	Is at the upper end of the bluff opposite the mouth of the Gallatin River. It is on the left bank of the Jefferson and Madison rivers, 50 feet from shore, 500 feet above the mouth of the Gallatin, and about 700 feet below the house on Miss Campbell's ranch, being at the lower end of small bottom bounded by low terrace, on which the Campbell house is situated. A fence running along end of bluff to the river passes 2 feet north of it. Marked by stone and pipe.	4,018.972
3 (Eagle Rock)	Is a copper bolt leaded vertically in the highest point of Eagle Rock, 150 feet from the river edge of rock, nearly midway between river and a snow shed over the Northern Pacific Railroad at this point. Eagle Rock is at lower end of Horseshoe Bend, about 6 miles below head of Missouri River, on the right bank.	4,035.375
4 (Magpie)	Is a copper bolt leaded vertically in a mass of rock about 20 feet east of first cut north of Magpie Station. Permanent bench-mark is about 30 feet north of east and west center line of cut and about 20 feet above track. It is on the right bank of river.	3,989.708

Descriptions and elevations of permanent bench-marks, Missouri River, etc.—Cont'd.

Number.	Description.	Elevation.
5 (Carolus Ranch).....	Is the northwest corner of small yard surrounding Carolus' house on Carolus Ranch. It is about 14 feet west of northwest corner of house, 2 feet from each fence, about 250 feet southeast of water's edge, and about 65 feet southeast of gravel bar. Carolus Ranch is on the right bank of Missouri River, 3¼ miles below Magpie Station, permanent bench-mark, is marked by a stone and pipe.	3,949.166
6 (Mammoth Spring)..	Is a copper bolt leaded vertically in bed-rock, 5,400 feet above Mammoth Spring Bridge, on the right bank of Missouri River. It is 70 feet south of Northern Pacific Railroad track, 23 feet south of fence, 140 feet south of water.s edge, and is on the west side of a rock bluff rising about 75 feet above track at a point where bluff merges into side of hill. Permanent bench-mark is about 20 feet above track. There are springs near water's edge just below it.	3,952.755
7 (Toston)	Is near upper ferry landing at Toston, Mont., on right bank of Missouri River. It is 180 feet west of Toston Railroad Depot, 90 feet from water's edge, and 50 feet south of road leading to ferry. Marked by stone and pipe.	3,889.448
8 (Reeve's Ranch)......	Is located on west edge of a terrace about 12 feet high on right bank of Missouri River, one-half of a mile north of Glen's house on Reeve's Ranch. A low, level field, 1,200 feet wide, lies between terrace and river. Permanent bench-mark is 360 feet west of a point on the Northern Pacific Railroad track, 100 feet north of Bridge No. 374; and is 1,250 feet east of water's edge. Marked by stone and pipe.	3,867.851
9. (Hossfeld's Ranch)..	Is located on Hossfeld's Ranch, on left bank of Missouri River, above Townsend, Mont., about 4 miles by rail or 6 miles by river. It is 30 feet from west edge of a bench which begins 1,400 feet from water's edge and extends back to hills about one-quarter of a mile distant, and is about 210 feet from northeast corner of Baxtell's house, the azimuth to which from permanent bench-mark is about 120°. Marked by stone and pipe.	3,847.986
10 (Townsend).........	Is located on the right bank of Missouri River, about one-half of a mile north of Townsend Railroad Station, about one-half of a mile from river, measured in direction perpendicular to track, and about three-quarters of a mile south of railroad bridge over Missouri River. It is about 60 feet west of a point on the track 80 feet north of Railroad Bridge No. 392, and about 7 feet west of railroad fence. Compass reading to Mile-post 1121 is 318°. Marked by stone and pipe.	3,795.991
11 (Murry's Ranch)....	Is on the ranch of John Murry, about 2¼ miles in a direct line, or 3¼ miles by river, below the railroad bridge at Townsend. It is at a fence corner, 4 feet from either fence; and is 1,200 feet east of river—being on the right bank—and about 850 feet west of irrigation ditch, on road leading to ford. It is said to be in the southwest corner of SW. ¼ of Sec. 8, T 7. N., R. 2 E. It is also five-eighths of mile west of Mr. McKnight's house. Marked by stone and pipe.	3,772.998
12 (Canton)............	Is on the right bank of Missouri River about 7 miles in a direct line, or about 10 miles by river, north of Townsend, Mont., and just 1½ miles west of Canton. If the road running west from Canton were continued, permanent bench-mark would be on south side of same. It is 45 feet southeast of northwest corner of Sec. 31, T. 7 N., R. 2 E., is 1,400 feet east of river bank, and is 500 feet north of an old line of fence-posts. Marked by stone and pipe.	3,748.461
13 (Pickering Ferry)...	Is located on the right bank of Missouri River, at "Pickering Ferry," which is operated by J. E. Smith, on whose land it is. This point is about 11 miles in a direct line, about 13 miles by road, or about 15 miles by river, below Townsend, Mont., and about 18 miles by river above Canyon Ferry, Mont. Permanent bench-mark is 140 feet south of water's edge, 45 feet east of center of road, 18 feet west of west corner of Mr. Smith's house, 3 feet east of fence, and in SE. ¼ of NE. ¼ of Sec. 12, T. 8 N., R. 1 E. Marked by stone and pipe.	3,715.963
14 (Blakes Ferry)	Is located on left bank of Missouri River, about 14 miles by river, or about 13 miles by road, above Canyon Ferry, on the land of Dr. Blake, who owns the ferry at this point. It is in the northeast corner of small yard surrounding Dr. Blake's house, is 38 feet from northeast corner of said house, 2½ feet from each fence, 215 feet west of water's edge, and 105 feet south of main road leading to ferry. Marked by stone and pipe.	3,698.363
15 (McMillan's Ranch).	Is located on the ranch of A. McMillan, on right bank of Missouri River, about 10 miles by river above Canyon Ferry, Mont. It is 73 feet north of northeast corner of McMillan's house, 1,750 feet south of water's edge, and about three-quarters of a mile north of foot of hills; and is in the southeast corner of NE. ¼ of of NE. ¼ of Sec. 17, T. 9 N., R. 1 E. Marked by stone and pipe.	3,688.257

Descriptions and elevations of permanent bench-marks, Missouri River, etc.—Cont'd.

Number.	Description.	Elevation.
16 (Cooney's Ranch)	Is on the ranch of Thos. J. Cooney, on right bank of Missouri River, about 5 miles above Canyon Ferry. It is in yard in front of Mr. Cooney's house, 30 feet west of house, 7 feet north of one fence, and 1 foot east of other; 300 feet east of water's edge, and near middle of south side of SW. ¼ of Sec. 30, T. 10 N., R. 1 E. House is just at foot of foot-hills. The road to Canyon Ferry passes directly in front of house. Marked by stone and pipe.	3,657.992
17 (Canyon Ferry)	Is located at Canyon Ferry—18 miles from Helena by road—on right bank of, and 300 feet east of, Missouri River; and 300 feet north of store and post-office. It consists of a copper bolt leaded vertically in natural rock, just east of road; and is 5 feet above level of road.	3,643.214
18 (Anderson's Ranch)	Is on the property of John Anderson, about 4½ miles below Canyon Ferry, about 2 miles above Stubbs Ferry, river distance, on right bank of Missouri River. It is on a bench between hills and bottom, about 18 feet above water surface, 205 feet north of water's edge, 56 feet west of small shed, about 3 feet west of center line of fence, and several hundred feet west of placer diggings. Is a stone and pipe.	3,628.908
19 (Stubbs Ferry)	Is at Stubbs Ferry, on left bank of Missouri River, 13 miles from Helena by road; is on summit of hill nearest ferry; summit of said hill is 600 feet southwest of water's edge, about 50 feet above road, and about 65 feet above water's surface. The road leading from ferry divides at the base of hill, one branch going to the left, the other to the right. The remains of an old flume run around hill about one-quarter of the way up. Marked by stone and pipe.	3,669.299
20 (Proposed dam)	Is about 3 miles below Stubbs Ferry, by river, on a rocky peninsula on left bank of Missouri River, about 75 feet above water, just above site of proposed dam. It is a copper bolt leaded vertically in a shaly rock on highest point within a radius of 300 feet. "U. S. B. M." is marked on vertical face of rock.	3,074.778
21 (El Dorado Bar)	Is located on the right bank of Missouri River, at the upper end of El Dorado Bar, 4,400 feet below mouth of Soup Creek. It is 168 feet west of an old log house on a bench 20 feet above the river. Marked by a stone and pipe; 940 feet from foot-hills.	3,611.071
22 (Beaver Creek)	Is located on the right bank of Missouri River, on a plateau 8 feet above water, 370 feet below the mouth of Beaver Creek. It is 50 feet from water's edge and 535 feet southwest of a small frame house. Marked by stone and pipe.	3,571.341
23 (Hilger's Ranch)	Is located on the left bank of Missouri River, on the land of N. Hilger, 420 feet below mouth of Spring Creek, 110 feet from river, 420 feet from foot of bluff, and half a mile northeast of Mr. Hilger's house. It is in a level pasture 8 feet above the river, and is marked by stone and pipe.	3,553.638
24 (Willow Creek)	Is on the right bank of Missouri River, 180 feet from water's edge, measured in a northerly direction from point where Willow Creek enters Missouri River. It is in a small level pasture 12 feet above river, is 530 feet from foot of bluff, and is in Sec. 16, T. 13 N., R. 3 E. Marked by stone and pipe.	3,538.117
25 (Copper Rock)	Is a copper bolt leaded vertically in top of the lowest of two large bowlders, about 1 mile below Copper Rock, and about 1½ miles above Cottonwood Creek. It is on the left bank.	3,504.691
26	Is located on the neck of Oxbow Bend. It is a copper bolt leaded vertically in a ledge on west face of a rocky cliff, about 5 feet above and on the east side of a wagon road that crosses the neck.	3,617.142
27 (Burke's Ranch)	Is on the land of W. P. Burke, on the right bank of Missouri River. It is several hundred feet below Mr. Burke's house and barns, at a sharp bend in the river, 2 feet east of a wire fence running from river to hills, and 30 feet from edge of bank which at this point rises sharply to 22 feet above water. Marked by stone and pipe.	3,473.788
28 (Prickly Pear Creek)	Is on the right bank of Missouri River, opposite the mouth of Prickly Pear Creek. It is on a plateau, which, at this point, is 42 feet above river. The bank is steep, and permanent bench-mark is not far from edge. Marked by stone and pipe.	3,484.771
29 (Craig)	Is located at Craig, Mont., on the left bank of Missouri River. It is 40 feet from water's edge, and 53 feet below the post supporting cable of Stickney Ferry. Marked by a stone and pipe.	3,436,848
30 (Dearborn River)	Is on the left bank of Missouri River, about 300 feet below mouth of Dearborn River. It is between the river and the Great Northern Railroad, 110 feet from water's edge, and 60 feet from a point on railroad 330 feet below east end of bridge over the Dearborn. It is also in a perpendicular line from section house to river, and marked by a stone and pipe.	3,428.715

Descriptions and elevations of permanent bench-marks, etc., Missouri River, etc.—**Cont'd.**

Number.	Description.	Elevation.
31	Is on the left bank of Missouri River, about 190 feet from water's edge, and 60 feet east of Great Northern Railroad track, 1,740 feet above Mile-post No. 42 on railroad, thus being about halfway between Dearborn River and Hardy. It is marked by a stone and pipe.	3,400.576
32 (Hardy)	Is located at Hardy, Mont., on left bank of Missouri River, about one-eighth of a mile below lower end of Halfbreed Rapids. It is between the river and Great Northern Railroad track, about 500 feet from water's edge, about 75 feet from main track, and about 100 feet below Hardy Section-house. Marked by a stone and pipe.	3,376.810
33	Is located on the left bank of Missouri River, at a pronounced bend nearly midway between Hardy and Cascade, Mont., nearer Hardy. It is about two-thirds up the river side of a small hill, about 200 feet from water and about 240 feet from a rocky point of same hill, which projects to water's edge. The Great Northern Railroad comes close to the river near this point, and then leaves it, being cut through the hill on which permanent bench-mark is. Marked by a stone and pipe.	3,368.794
34 (Cascade)	Is located at Cascade, Mont., on left bank of Missouri River. It is 215 feet above depot, in line with front of said building, about 475 feet from river and about 25 feet south of a ravine running nearly east and west from river. Marked by a stone and pipe.	3,361.502
35	Is located on the left bank of Missouri River, at pronounced bend in river, about 4 miles by railroad below Cascade. It is about 170 feet from water's edge and about 1,000 feet from the Great Northern Railroad. The river bank at this point is steep and about 30 feet above water. Marked by a stone and pipe.	3,341.443
36 (Muddy Creek)	Is on the left bank of Missouri River, at bend in river, about 7 miles by railroad below Cascade. The Great Northern Railroad comes close to the river at this point and leaves it again. There is a high hill back of permanent bench mark. It is three-quarters of a mile below Fort Mountain Creek—also called Muddy Creek—and is marked by a stone and pipe.	3,328.525
37 (sec. 24, T. 9 N., R. 1 E.)	Is on the left bank of Missouri River, opposite a sharp bend, just above which the river is bordered by willows. It is between the Great Northern Railroad and river, about 2,100 feet from water's edge, and about 1,100 feet east of Great Northern Railroad. It is at a fence corner, 4 feet from a stone mounment at center of Sec. 24, T. 9 N., R. 1 E. Marked by a stone and pipe.	3,321.839
38 (Ulm)	Is on the left bank of Missouri River, at Ulm, Mont., which is at a bend in river where Great Northern Railroad comes close to it. It is 30 feet north of track, and in line with east end of section house, and 95 feet therefrom. It is 215 feet from water's edge, and marked by a stone and pipe.	3,324.737
39	Is on the left bank of Missouri River, between two bends in river, about 4 miles by railroad below Ulm. It is on the west side of a fence running north and south, which strikes the Great Northern Railroad about 1,000 feet above Mile-post 11 from Great Falls, Mont. It is about 250 feet from water's edge, and about 200 feet from edge of bank, which is about 30 feet high, and steep. Marked by a stone and pipe.	3,445.907
40	Is located on the left bank of Missouri River, opposite lower end of Buckshot Island, which is just above a great bend in river. The Great Northern Railroad here comes close to the river, and then leaves it. Permanent bench-mark is between railroad and river, 50 feet from track, and 600 feet (surface measure) from water's edge. It is also 125 feet from a wagon road running between railroad and river, and is 3,200 feet above Mile-post 6 from Great Falls, Mont.	3,411.242
41 (Loberg's Place)	Is on the right bank of Missouri River, on the property of N. P. Loberg, about 3 miles above Great Falls, Mont. It is in a fence corner, near a cesspool, and is about 160 feet from water's edge. Coördinates to permanent bench-mark from northeast corner of house are, 85 feet in direction parallel to river, and 60 feet in direction perpendicular to river. Marked by a stone and pipe.	3,308.651
42 (Great Falls Bridge)	Is a copper bolt leaded vertically in the upstream end of cap stone of pier at the end of third iron truss from right bank of river of the Great Falls, Mont., highway bridge across the Missouri River. This bridge, the only highway bridge at Great Falls at the present time, is at the foot of First avenue, north.	3,305.363
43 (Dam, Great Falls)	Is at the top of cap stone of gate pier at north end of dam built by the Great Falls Power and Townsite Company at Black Eagle Falls, about 3¼ miles below railroad bridge.	3,292.284
44	Is located on the left bank of Missouri River, opposite the Union Lead Smelter, about 2 miles below the dam at Black Eagle Falls. It is about 25 feet from bank which, at this point, is nearly perpendicular and about 25 feet high. Marked by a stone and pipe.	3,248.551

Descriptions and elevations of permanent bench-marks, Missouri River, etc.—Cont'd.

Number.	Description.	Elevation.
45 (Crooked Falls)	Is located on the left bank of Missouri River, opposite the upper end of Crooked Falls. It is about 175 feet from bank, which, at this point, is perpendicular and about 50 feet high. Marked by a stone and pipe.	3,106.529
46	Is located on the left bank of Missouri River, about 2 miles below Crooked Falls. It is opposite the upper end of the larger of two small islands, which are about 4 feet high and covered with bushes. It is about 60 feet from edge of bank, which is here about 50 feet high. Marked by a stone and pipe.	3,133.090
47 (The Great Falls)	Is located on the left bank of Missouri River, about 1,500 feet below the Great Falls, which are 12 miles below Great Falls City, Mont. It is on a rocky cliff about 100 feet above the water, is about 60 feet from edge of cliff, and about 80 feet from a wagon road that winds from the top of hill past the house at present occupied by Mr. Fitch to water's edge. Permanent bench-mark is a copper bolt leaded vertically into solid rock.	2,990.681
48 (Portage Coulee)	Is on the right bank of Missouri River, 5½ miles below the Great Falls, and 800 feet above the lower end of a flat about 100 feet wide and one-half of a mile long. There is a fall of 2 to 5 feet, and a rock bar, about 300 feet below permanent bench-mark. It is one-half of a mile below the dry mouth of Belt Creek, where there are bad rapids and a rock bar. On the opposite bank there is low ground for a mile or more down to point opposite permanent bench-mark. Marked by a stone and pipe; 1¾ miles above Portage Coulee.	2,779.346
49 (Highwood Creek)	Is about three-quarters of a mile below ranch of John Smith, and about 1 mile above ranch of W. T. Blevins; on the left bank, about 1 mile above Highwood Creek, 400 feet from water's edge, midway between river and foot of hills; on a flat about one-third of a mile long and 15 to 20 feet above the river; opposite a point on Great Northern Railroad about 3 miles north of Portage Station. Marked by a stone and pipe.	2,743.876
50 (Huntsburger's Ranch)	Is on the ranch of John Huntsberger, on left bank of Missouri River, about 2 miles below an island (1,800 feet long and 400 feet wide). Ranch is on bottom, about 1½ miles long and 1,000 feet wide, and 15 to 20 feet above the river. Permanent bench-mark three-fifths of a mile above shanty on Huntzberger's Ranch, and is also about 1½ miles above ranch of Winnie Evans, and is opposite a point on Great Northern Railroad about 2 miles south of Sydney Section-house. The river here is about 350 feet wide, and on opposite shore is a bluff bank 50 to 150 feet high, backed by hills of same height. On the left bank, back of bottom, the hills are of the same height. Permanent bench-mark is marked by a stone and pipe.	2,712.211
51	Is on the left bank of Missouri River, about one-half of a mile below a large island (1,700 by 300 feet); about 1,000 feet below the upper end of a bottom about one-half mile long and 1,000 feet wide which is from 10 to 15 feet above the river, about 120 feet from water's edge and about 600 feet south of a water road leading from Great Northern Railroad to river. Beginning at the lower end of the bottom is an island one-half of a mile long, and below this an island 1,200 feet long. Permanent bench-mark is also about 1½ miles above the ranch of David Brown, and is marked by a stone and pipe.	2,688.386
52 (Gibson's Ranch)	Is on the left bank of Missouri River, on the ranch of C. S. Gibson, about three-quarters of a mile above residence on ranch; 250 feet from water's edge, 110 feet west of an old shack, and about 10 miles by river, or about 8 miles by shortest road, above Fort Benton, Mont. Marked by a stone and pipe.	2,631.6[illegible]1
53 (Cottonwood Bottom)	Is on the left bank of Missouri River, opposite Cottonwood Bottom, about 5 miles by river or 3½ miles by road, above Fort Benton, Mont. It is at the upper end of the ranch of Jeff. Deverill, about five-eighths of a mile above dwelling on ranch and 225 feet from water's edge. Marked by a stone and pipe.	2,635.1[illegible]9

APPENDIX A 3.

ANNUAL REPORT OF MR. O. B. WHEELER, ASSISTANT ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
St. Louis, Mo., June 30, 1891.

SIR: I have the honor to submit the following report on the field work and reductions of the secondary triangulation of the Missouri River during the season of 1890, together with the reductions of work done in 1889 not before reported:

FIELD WORK, 1890.

The field work under my charge was to complete the triangulation between the closing of Assistant Engineer G. A. Marr's work at Sioux City, Iowa, in 1889, and the beginning of my work in 1886–'87 at Fort Leavenworth, Kans., being a river distance of 385 miles.

In accordance with your instructions, I left St. Louis on June 16. The two quarter boats, Nos. 7 and 8, on the bank 3 miles above Sioux City, were reached and turned over to me on the 18th. On the morning of the 19th Capt. C. B. Tilden arrived from Mandan, N. Dak., with quarter boats Nos. 5 and 6, which he turned over to me, after assisting to launch quarter boats Nos. 7 and 8. On the 21st the four quarter boats were dropped to Sioux City, and, on Monday, the 23d, Nos. 7 and 8 were turned over to Assistant Engineer D. W. Wellman.

On July 9 work was completed to Onawa, Iowa, working with a reduced force, when Assistant Engineer R. F. Grady, who had been detained on special surveys in Missouri, arrived, and on the 10th Assistant Engineer O. H. B. Turner, who had been the observer up to this time, with Recorder J. W. Woermann, left to assist Mr. Marr in Montana.

The organization of my party was then as follows, the second observer being Assistant Engineer C. W. Williams:

On quarter boat No. 5: myself, 1 rodman, 1 mate, 1 cook, 1 foreman, 1 boatman, and 3 laborers.

On quarter boat No. 6: 2 observers, 2 recorders, 2 rodmen, 1 mate, 1 cook, 1 boatman, and 6 laborers.

Mr. Turner had used the Troughton & Simms non-repeating 10-inch theodolite No. 1, which Mr. Williams, observer on the right bank, continued to use. Mr. Grady used on the left bank, the Troughton & Simms 12-inch repeating theodolite, but treated it as a non-repeater. Eight combined results were obtained as the measurement of an angle, and the angle closing the horizon was measured. The theodolites were generally mounted on the large portable tripods, but in two cases timber stations were found necessary. The targets were generally raised above the observer on a timber frame, and were always concentric with the station. A quadrilateral system of triangulation was obtained throughout, and 85 per cent. of the triangles closed within the primary limit of 3″ before adjustment.

Measurements of the Blair base, near Blair, Nebr., 2¼ miles in length, were made on two consecutive evenings, with results differing but eight-hundredths of an inch, or 1 in 2,000,000. On four nights, observations on Polaris at eastern elongation, with the necessary time-star observations, were made for the azimuth of △ west base from △ east base. Theodolite Troughton & Simms 10-inch No. 1 was used, and the level correction was eliminated by alternating direct observations on Polaris with its image from an artificial horizon—a method much to be commended when the mercury is not disturbed by wind or local disturbances. The first night's work was rejected, on account of the high wind and bad conditions.

RÉSUMÉ OF FIELD WORK.

Secondary stations built	68
Secondary stations occupied	72
Tertiary stations located	24
Tertiary stations occupied	15
Angles measured in main system	285
Angles measured to locate other points	150
Buildings, land survey marks, etc., connected with	79
Azimuth observations, number of nights	4
Base lines measured	1
Miles of river covered	385

REDUCTION OF WORK OF 1889, TROVER POINT TO BISMARCK.

(For the report on the field work and the reduction of the Buford base, see the Chief of Engineers' Report for 1890, page 3398.)

The reduction of this work was about completed one year ago, but it was thought best not to publish it until a connection was made with the triangulation in Missouri and a final initial latitude and longitude adopted for the whole river. The method of reduction is continued as explained in former reports. The individual angles were tabulated and an adjustment for closing the horizon made, and then the locally adjusted angles were treated as the observed angles, each adjustment being, generally, for a simple quadrilateral.

The number of such adjustments between the Trover Point base and the Buford base was 22, and the number between the Buford base and the Bismarck base was 27. In the total 49 adjustments there were 439 angles entering, and the corrections to these lie as follows:

Between 0″ and 1″	286
Between 1″ and 2″	119
Between 2″ and 3″	30
Between 3″ and 4″.3	4

The computation of the triangulation from Trover Point to Fort Buford was through 45 triangles, and the axial distance was 193 miles; and the computation from Fort Buford to Bismarck was through 61 triangles, and the axial distance was 220 miles.

The observed azimuth at Fort Buford agreed with that by computation from Trover Point within less than one second, and was about the mean of the computed from Fort Benton and Trover Point; and the measured Buford base was greater than that computed from Trover Point by twenty-three hundredths of a foot, or 1 in 50,000 parts of the base. The observed azimuth at Bismarck was 13″.84 less than that computed from Fort Buford; and the measured Bismarck base was less than that computed from Fort Buford by 2.15 feet, or 1 in 7,500 parts of the base.

The results for observed azimuth at Fort Buford and Bismarck are found in table of azimuths, Appendix A 4, and tables of the final results of the triangulation are found in Tables III and IV, Appendix A 4.

REDUCTION OF WORK OF 1890, SIOUX CITY TO FORT LEAVENWORTH.

The method of reduction was the same as that just given, or referred to. The number of adjustments from the line △ Round Cap – △ Emerson, near Sioux City, upon which line Mr. Marr closed in 1889, to the Blair base system was 6; and the number below to the line △ Weston – △ Sheridan, where the work of 1886–'87 began, was 27. In the total 33 adjustments there were 285 angles entering, and the corrections to these lie as follows:

Between 0″ and 1″	200
Between 1″ and 2″	68
Between 2″ and 3″	15
Between 3″ and 4″.3	2

The computation of the triangulation from Running Water base to the Blair base system was through thirty-four triangles and an axial distance of 155 miles; and from the Blair base to the line △ Weston—△ Sheridan, was through fifty-six triangles and an axial distance of 189 miles.

The observed azimuth at the Blair base was 6.20″ less than that computed from the Running Water base; and the measured length of Blair base was greater than that computed from either the Running Water base or the Beverly base near Fort Leavenworth by seven-tenths of a foot, or 1 in 18,400 parts of the base.

The results for observed azimuth at the Blair base are herewith appended, and the reduction of the Blair base is found in Table of Azimuths, Appendix A 4; and tables of the final results of the triangulation are found in Tables VII and VIII, Appendix A 4.

Very respectfully, your obedient servant,

O. B. Wheeler,
Assistant Engineer.

First Lieut. J. C. Sanford,
Corps of Engineers, U. S. A.,
Secretary Missouri River Commission.

MEASUREMENT OF THE BLAIR BASE.

The two measurements of the Blair base are expressed by the following equations:

$$(1)\ 43\,T + 0'.6009 + 0'.6667 + 0'.3167 - 0'.0199 - 0'.0023 = 12{,}903'.2180.$$
$$(2)\ 43\,T + 0'.6674 + 0'.6667 + 0'.2592 - 0'.0199 - 0'.0047 = 12{,}903'.2246.$$

Where

First term is number of tapes multiplied by the length of tape at 62° F. (Where T = 300.03851 feet. See Report for 1889, p. 2759.)

Second term is temperature correction to reduce 43 tapes at tape temperature to 62° F. (Where coefficient of expansion = 0.00000687 for 1° F. See same reference.)

Third term is distance set forward on zincs.

Fourth term is distance between the end of last tape and △ west base.

Fifth term is correction for inclination of tape.

Sixth term is the correction for sag, where one supporting stake was missing in first measurement and two (not consecutive) were missing in second measurement.

The ***second member*** is the corrected independent result for each measurement.

The mean of the two measurements	$= 12{,}903'.2213 \pm 0'.0022.$
Reduction to sea level for 1,015'.3 elevation	$= -\ 0'.6252$
Blair base reduced to sea level	$= 12{,}902'.5961 \pm 0'.0022.$

Blair base.—Temperatures during measurements.

No. of tape.	First measurement.		Second measurement.		No. of tape.	First measurement.		Second measurement.	
	Time, July 25, 1890, p. m.	Thermometer, 5114.	Time, July 26, 1890, p. m.	Thermometer, 5114.		Time, July 25, 1890, p. m.	Thermometer, 5114.	Time, July 26, 1890, p. m.	Thermometer, 5114.
	h. m.	°	*h. m.*	°		*p. m.*	°	*p. m.*	°
1	7 10	74.8	7 14	74.9	24	8 00	67.1	7 58	69.0
2	12½	74.0	16	74.2	25	01	67.1	8 00	68.2
3	14	74.4	18	74.2	26	04	65.0	04	66.4
4	16	74.8	20	74.2	27	09	64.9	06	66.2
5	18	74.6	22	74.0	28	10	64.6	08	65.5
6	20	74.8	24	73.9	29	12	64.7	09½	65.4
7	22	73.6	26	73.6	30	15	64.2	11	65.2
8	24	73.8	28	72.2	31	17	63.4	13	65.0
9	26	73.0	30	71.8	32	19	65.2	16	65.8
10	27½	72.4	31½	72.0	33	21	65.6	16½	66.0
11	29	71.6	33	72.4	34	22	66.4	19	66.0
12	32	71.2	35	72.7	35	24	65.6	21	66.8
13	34	71.0	37½	71.8	36	26	65.2	22	67.5
14	36	71.0	40	71.6	37	29	65.0	24	66.8
15	37	71.4	41½	71.2	38	31	64.6	26	67.2
16	39	71.0	43	71.2	39	32½	64.6	28	68.3
17	40½	71.0	45	71.6	40	34	65.3	30	68.2
18	43	70.6	47	71.0	41	36	64.8	34	66.2
19	44½	71.0	49	70.4	42	37½	65.5	36	66.2
20	53	68.4	52	69.4	43	43½	65.1	39	66.6
21	55	68.5	53	70.0					
22	57	69.0	55	69.1	Mean	....	68.78	....	69.53
23	58	68.4	57	69.9					

Remarks.—Thermometer No. 5101 was broken in an endeavor to close the broken column of mercury. Thermometer No. 5114 was at the middle of the tape and read independently by two observers, the mean of the readings being the one here given. The correction to thermometer reading is less than one-tenth of a degree and is not applied. (See Report for 1890, page 3402.)

Blair base.—Corrections for inclination of tape.

No. of stake.	Elevation.	Differences of elevation.	Correction	No. of stake.	Elevation.	Differences of elevation.	Correction.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
△ E. B	15.05	....	....	23	11.66	−0.49	0.0004
Zinc E. B	16.65	....	....	24	11.60	−0.06	0.0000
1	15.60	−1.05	0.0018	25	11.58	−0.02	0.0000
2	16.35	+0.75	0.0001	26	11.29	−0.29	0.0001
3	16.05	−0.30	0.0001	27	11.18	−0.11	0.0000
4	15.68	−0.37	0.0002	28	10.88	−0.30	0.0001
5	15.21	−0.47	0.0004	29	10.99	+0.11	0.0000
6	14.57	−0.64	0.0007	30	11.14	+0.15	0.0000
7	14.64	+0.07	0.0000	31	10.72	−0.42	0.0008
8	14.50	−0.14	0.0000	32	10.90	+0.18	0.0001
9	15.91	+1.41	0.0034	33	11.00	+0.10	0.0000
10	16.34	+0.43	0.0003	34	10.96	−0.04	0.0000
11	16.91	+0.57	0.0005	35	11.08	+0.12	0.0000
12	16.22	−0.69	0.0008	36	11.09	+0.01	0.0000
13	15.32	−0.90	0.0014	37	10.89	−0.20	0.0001
14	14.07	−1.25	0.0026	38	10.81	−0.08	0.0000
15	13.87	+0.20	0.0001	39	10.64	−0.17	0.0000
16	14.59	+0.72	0.0009	40	10.03	−0.61	0.0006
17	14.00	−0.59	0.0006	41	9.57	−0.46	0.0004
18	14.37	+0.37	0.0002	42	9.60	+0.03	0.0000
19	13.45	−0.92	0.0014	Zinc W. B	9.24	−0.36	0.0002
20	13.02	−0.43	0.0003	△W. B	7.59	....	....
21	11.98	−1.04	0.0018				
22	12.15	+0.17	0.0000	Total correction	....	....	−0.0199

REMARKS.—Elevations are above the water surface of the Missouri River at noon of July 25, 1890, at a point opposite "B. M. 27" (or 440 (27) of report 1888). Water surface was 12.602 feet on above date below this B. M. B. M. 27 = 602.256 feet above the St. Louis directrix, or = 1,015.00 above sea. The mean elevation of the base line—zinc E. B. to zinc W. B.— =0.314 feet above B. M. 27; or mean elevation of base line =1,015.3 feet above sea level.

Blair base.—Measured differences on zincs.

Number of tape.	First measurement—second measurement.			Number of tape.	First measurement—second measurement.		
	Readings on zincs.	Correction.	Reduced.		Readings on zincs.	Correction.	Reduced.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
1	±0.00	....	±0.00	23	0.08	....	0.08
2	+0.02	....	+0.02	24	0.13	....	0.13
3	−0.01	....	−0.01	25*	0.12	....	0.12
4	−0.04	....	−0.04	26†	−7.83	+8.00	0.17
5	+0.03	....	+0.03	27	+0.19	±0.00	0.19
6	±0.00	....	±0.00	28	0.22	....	0.22
7	+0.02	....	+0.02	29	0.20	....	0.20
8	±0.00	....	±0.00	30	0.18	....	0.18
9	−0.01	....	−0.01	31	0.28	....	0.28
10	−0.02	....	−0.02	32	0.26	....	0.26
11	+0.03	....	+0.03	33	0.24	....	0.24
12	±0.00	....	±0.00	34	0.32	....	0.32
13	+0.02	....	+0.02	35	0.29	....	0.29
14	0.03	....	0.03	36	0.35	....	0.35
15	0.02	....	0.02	37	0.38	....	0.38
16	0.02	....	0.02	38	0.49	....	0.49
17	0.05	....	0.05	39	0.59	....	0.59
18	0.04	....	0.04	40	0.64	....	0.64
19	0.03	....	0.03	41	0.65	....	0.65
20	0.07	....	0.07	42	0.69	....	0.69
21	0.06	....	0.06	43	0.69	....	0.69
22	0.07	....	0.07				

* Set ahead 8 inches on zinc, 25 on second measurement.
† Set ahead 8 inches on zinc, 26 on first measurement.

REMARKS.—The readings from the zinc strips were made in the field before the strips were taken from the stakes and check readings were made in the office where the strips are on file.

A puncture with a free-hand dash (thus ·—) marks the first measurement, and a puncture with a free-hand cross (thus ·+) marks the second measurement.

The zinc strips are of great assistance in the rapidity of measurement and they show the accuracy with which the work can be done.

APPENDIX A 4.

TABLES OF RESULTS OF THE SECONDARY TRIANGULATION OF THE MISSOURI RIVER.

NOTES ON THE TABLES OF RESULTS.

The triangulation of the Missouri River is now complete from the Three Forks at Gallatin, Mont., or the source, to the mouth at the Mississippi River.

The tables of results, with sketches and descriptions of stations, are from base line to base line, and thus constitute ten sections, of which eight are herewith given. For the remaining 2, the ninth and tenth sections—Fort Leavenworth to Glasgow and Glasgow to St. Louis—see the Chief of Engineers' Report for 1887. The second section, Fort Benton to Trover Point, is herewith republished from the same report with a correction of +14″.25 in latitude and +1″.27 in longitude, that all the ten sections may be reduced to one common origin. This origin is the Morrison Observatory at Glasgow, Mo., the latitude and longitude of which are as given in "Publications of the Morrison Observatory, Glasgow, Mo., No. 1, 1885;" namely, latitude 39° 13′ 45″.59, and longitude, 92° 49′ 30″, the longitude of Washington from Greenwich being taken as $5^h\ 08^m\ 12^s.09$. (The approximate latitude and longitude of the flagstaff at Fort Benton, Mont., were adopted, temporarily, from the Report of the Northern Boundary Survey, 1878, until a connection with a well-established fixed point could be made.)

The sections and tables are for extents as follows:

No. of section or table.	Locality.	Axial length of net of triangulation.
		Miles.
I	Three Forks to Fort Benton	184
II	Fort Benton to Trover Point	180
III	Trover Point to Fort Buford	193
IV	Fort Buford to Bismarck	220
V	Bismarck to Pierre	204
VI	Pierre to Running Water	184
VII	Running Water to Blair	155
VIII	Blair to Fort Leavenworth	189
IX	Fort Leavenworth to Glasgow	133
X	Glasgow to St. Louis	*198
	Total axial length	1,840

* To mouth of river.

There were ten base lines measured and their lengths, together with the closures of one upon the next succeeding, are shown as follows:

Table of bases.

Name of base.	Length.	Discrepancies. In the seventh place of logarithms, computed from next above.	Discrepancies. Ratio.
	Feet.		*Miles.*
Three Forks	4,800.00		
Benton	9,869.05	Too large by 654	1 in 6,600
Trover Point	9,710.86	Too large by 981	1 in 4,400
Buford	11,400.35	Too small by 87	1 in 50,000
Bismarck	16,649.55	Too large by 578	1 in 7,500
Pierre	11,999.89	Too small by 400	1 in 10,900
Running Water	14,101.53	Too large by 350	1 in 12,100
Blair	12,902.60	Too small by 236	1 in 18,400
Beverly	7,933.52	Too large by 229	1 in 18,400
Glasgow	7,923.11	Too large by 305	1 in 15,000
Cedar-Medlock, U. S. Coast and Geodetic Survey	56,604.09	Too large by 199	1 in 22,000

These bases were taken as absolute and the discrepancies were distributed between bases by quadrilaterals, so that the lower line of a quadrilateral computed from the upper line may differ by as much as 25 in the seventh place of logarithms in some cases.

The azimuth of each of the 10 base lines was observed and the results by stars are here given. The closure of one upon the next succeeding was generally less than the discrepancies in the results by nights for any one station, and no attempt was made to distribute discrepancies in azimuth; but the observed azimuth was adopted when arrived at, except that the azimuth at Fort Benton was continued to Fort Buford, and that at Bismarck was continued to Blair, and the azimuth at Fort Benton was used in computing to Three Forks, and that at Fort Leavenworth in computing to Blair.

Table of azimuths.

AT THREE FORKS, MONTANA. AZIMUTH OF LINE △ SOUTH BASE TO △ NORTH BASE.

[Instrument: Troughton & Simms 10-inch theodolite, No. 2.]

Observer.	Star, date, etc.	Result for star.			Resulting azimuth.		
		°	′	″	°	′	″
O. H. B. Turner	Polaris, near eastern elong., July 21, 1890	161	47	54.75			
Do	Polaris, near eastern elong., July 22, 1890	161	47	55.43			
Do	Polaris, near eastern elong., July 25, 1890	161	47	53.66			
T. C. Thomas	Polaris, near eastern elong., July 26, 1890	161	47	59.33	161	47	55.79

AT FORT BENTON, MONTANA. AZIMUTH OF LINE △ EAST BASE TO △ WEST BASE

[Instrument: Troughton & Simms 10-inch theodolite, No. 1.]

		°	′	″	°	′	″
D. C. Humphreys	Polaris, near eastern elong., July 19, 1885	73	01	04.26			
Do	Polaris, near eastern elong., July 20, 1885	73	01	04.17			
Do	Polaris, near eastern elong., July 23, 1885	73	01	08.76	73	01	05.73

AT TROVER POINT, MONTANA. AZIMUTH OF LINE △ WEST BAST TO △ EAST BASE.

[Instrument: Troughton & Simms 10-inch theodolite, No. 1.]

		°	′	″	°	′	″
Bathurst Smith	Polaris, near eastern elong., Sept. 26, 1885	251	29	10.71			
Do	δ Ursæ Minoris, near west. elong., Sept. 26, 1885	251	29	12.11			
D. C. Humphreys	Polaris, near eastern elong., Sept. 27, 1885	251	29	07.71	251	29	10.18

AT FORT BUFORD, NORTH DAKOTA. AZIMUTH OF LINE △ WEST BASE TO △ EAST BASE.

[Instrument: Troughton and Simms 10-inch theodolite, No. 1.]

		°	′	″	°	′	″
R. F. Grady	Polaris, near eastern elong., Aug. 8, 1889 (weight 2).	262	58	43.21			
Do	Polaris, near eastern elong., Aug. 9, 1889 (weight 8).	262	58	40.85			
Do	δ Ursæ Minoris, near west. elong., Aug. 9, 1889 (weight 10).	262	58	45.05			
Do	Polaris, near eastern elong., Aug. 10, 1889 (weight 10).	262	58	43.79			
Do	Polaris, near eastern elong., Aug. 11, 1889 (weight 10).	262	58	43.49			
E. E. Wall	Polaris, near eastern elong., Aug. 12, 1889 (weight 5).	262	58	40.85	262	58	43.04

Table of azimuths—Continued.

AT BISMARCK, NORTH DAKOTA. AZIMUTH OF LINE △ NORTH BASE TO △ SOUTH BASE.

[Instrument: Troughton & Simms 10-inch theodolite, No. 1.]

		°	′	″	°	′	″
R. F. Grady	Polaris, near western elong., Nov. 19, 1889	341	58	26.26			
Do	Polaris, near western elong., Nov. 20, 1889	341	58	27.20	341	58	26.73

AT PIERRE, SOUTH DAKOTA. AZIMUTH OF LINE △ WEST BASE TO △ CEMETERY.

[Instrument: Troughton & Simms 10-inch theodolite, No. 2.]

		°	′	″	°	′	″
J. J. Sanders	Polaris, near eastern elong., July 29, 1889	237	48	42.35			
Do	Polaris, near eastern elong., Aug. 1, 1889	237	48	43.05	237	48	42.70

AT RUNNING WATER, SOUTH DAKOTA. AZIMUTH OF LINE △ SOUTH BASE TO △ KELLY.

[Instrument: Troughton & Simms 12-inch repeating theodolite.]

		°	′	″	°	′	″
J. J. Sanders	δ Ursæ Minoris, near western elong., Oct. 16, 1889 (weight 1).	179	10	51.06			
Do	51 Cephei, near eastern elong., Oct. 16, 1889 (weight 1).	179	11	06.06			
Do	Polaris, near eastern elong., Oct. 16, 1889 (weight 2).	179	11	10.59			
Do	Polaris, near eastern elong., Oct. 17, 1889 (weight 2).	179	11	14.62	179	11	07.92

AT BLAIR, NEBRASKA. AZIMUTH OF LINE △ EAST BASE TO △ WEST BASE.

[Instrument: Troughton & Simms 10-inch theodolite, No. 1.]

		°	′	″	°	′	″
R. F. Grady	Polaris, near eastern elong., July 31, 1890	89	55	17.22			
C. W. Williams	Polaris, near eastern elong., Aug. 1, 1890	89	55	16.13			
R. F. Grady	Polaris, near eastern elong., Aug. 2, 1890	89	55	20.43	89	55	17.93

AT FORT LEAVENWORTH, KANSAS. AZIMUTH OF LINE △ AZIMUTH TO △ NORTH-EAST BASE.

[Instrument: Troughton & Simms 10-inch theodolite, No. 1.]

		°	′	″	°	′	″
C. V. Mersereau	δ Ursæ minoris, near west. elong., Oct. 7, 1886	265	39	52.33			
Do	δ Ursæ minoris, near west. elong., Oct. 9, 1886	265	39	51.34			
Bathurst Smith	Polaris, near eastern elong., Oct. 10, 1886	265	39	52.15			
Do	δ Ursæ minoris, near west. elong., Oct. 10, 1886	265	39	53.58	265	39	52.35

AT GLASGOW, MISSOURI. AZIMUTH OF LINE △ GLASGOW TO △ EAST BASE.

[Instrument: Troughton & Simms 10-inch theodolite, No. 2.]

		°	′	″	°	′	″
C. V. Mersereau	Polaris, near western elong., Nov. 9, 1885	25	04	10.44			
Do	δ Ursæ minoris, near west. elong., Nov. 10, 1885	25	04	10.77			
Do	51 Cephei, near eastern elong., Nov. 10, 1885	25	04	08.02	25	04	09.74

TABLE I.—*Tabulated results of secondary triangulation from Three Forks to Fort Benton, Mont.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first, in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
South base	49 28 55.19	56.32	161 47 52.36	4,799.997	1,463.026	45 54 58.35	111 29 43.63
North base	94 54 52.80	53.80	246 52 43.32	6,267.99	1,910.47	45 55 43.36	111 30 04.84
Gallatin	35 36 09.00	09.88	31 17 32.03	8,214.81	2,503.85	45 56 07.65	111 28 43.28
North base	38 41 45.32	45.54	246 52 43.32	6,267.99	1,910.47		
Gallatin	92 32 34.60	33.93	159 26 15.84	5,211.19	1,588.36		
Campbell	48 45 41.90	40.53	28 11 37.76	8,327.22	2,538.11	45 56 55.82	111 29 09.18
Gallatin	69 46 25.05	24.08	159 26 15.84	5,211.19	1,588.36		
Campbell	57 25 45.19	44.91	282 00 12.32	6,139.12	1,871.18		
Cedar Hill	52 47 51.82	51.01	49 13 22.37	5,513.61	1,680.53	45 56 43.20	111 27 44.22
Campbell	68 38 12.85	15.17	282 00 12.32	6,139.12	1,871.18		
Cedar Hill	63 54 33.54	32.90	165 55 46.28	7,760.44	2,365.36		
Spring	47 27 12.19	11.93	33 22 39.02	7,483.82	2,281.05	45 57 57.52	111 28 10.92
Cedar Hill	65 48 34.85	35.24	165 55 46.28	7,760.44	2,365.36		
Spring	71 54 06.71	06.31	274 01 20.77	10,520.67	3,206.67		
Huntley	42 17 18.66	18.45	51 45 49.10	10,962.85	3,341.44	45 57 50.20	111 25 42.38
Spring	78 05 41.58	41.39	274 01 20.77	10,520.67	3,206.67		
Huntley	65 24 33.81	33.35	159 27 40.92	17,308.29	5,275.52		
Beattie	36 29 45.15	45.26	15 56 24.33	16,084.46	4,902.50	46 00 30.20	111 27 08.39
Huntley	60 54 52.98	52.14	159 27 40.92	17,308.29	5,275.52		
Beattie	58 56 36.96	37.73	280 30 01.31	17,440.65	5,315.86		
Clark	60 08 29.67	30.13	40 24 25.88	17,096.79	5,211.05	45 59 58.75	111 23 05.51
Beattie	78 05 09.82	08.12	280 30 01.31	17,440.65	5,315.86		
Clark	46 48 21.82	21.09	147 21 17.14	20,804.87	6,341.26		
Sawyer	55 06 32.58	30.79	22 25 53.47	15,501.50	4,724.81	46 02 51.66	111 25 44.60
Clark	42 07 41.65	41.68	147 21 17.14	20,804.87	6,341.26		
Sawyer	60 35 55.76	56.26	266 43 26.38	14,307.21	4,360.80		
Magpie	77 16 21.48	22.06	9 29 30.07	18,581.85	5,663.70	46 02 59.68	111 22 22.11
Sawyer	65 33 44.49	43.22	266 43 26.38	14,307.21	4,360.80		
Magpie	67 08 22.47	21.51	153 54 13.68	17,724.10	5,402.25		
Pinnacle	47 17 55.93	55.27	21 10 49.31	17,939.07	5,467.78	46 05 36.80	111 24 12.72
Magpie	31 50 12.18	11.87	153 54 13.68	17,724.10	5,402.25		
Pinnacle	66 48 34.19	34.79	267 04 19.22	9,456.88	2,882.43		
Carolus	81 21 12.79	13.34	5 44 42.40	16,479.30	5,022.85	46 05 41.54	111 21 58.72
Pinnacle	100 23 43.26	42.48	267 04 19.22	9,456.88	2,882.43		
Carolus	48 42 26.12	25.41	135 48 21.17	18,113.94	5,521.08		
Painted Rock	30 53 52.01	52.11	346 40 04.10	13,836.93	4,217.46	46 07 49.71	111 24 57.99
Carolus	38 24 32.88	32.18	135 48 21.17	18,113.94	5,521.08		
Painted Rock	76 30 15.19	14.89	239 15 57.08	12,408.21	3,781.99		
Lone Bush	65 05 14.12	12.93	354 12 33.33	19,420.91	5,919.44	46 08 52.28	111 22 26.53
Painted Rock	39 50 10.23	10.55	239 15 57.08	12,408.21	3,781.99		
Lone Bush	83 14 33.99	34.63	142 32 20.92	9,486.20	2,891.37		
Toston	56 55 14.64	14.82	19 26 36.63	14,705.54	4,482.21	46 10 06.61	111 23 48.50
Painted Rock	70 14 25.71	26.16	199 25 46.52	14,705.54	4,482.21		
Toston	67 29 15.42	14.60	86 55 51.25	20,574.76	6,271.13		
Dougherty	42 16 19.05	19.24	309 08 39.99	20,196.07	6,155.71	46 09 55.63	111 28 40.36
Toston	73 13 54.10	54.65	86 55 51.25	20,574.76	6,271.13		
Dougherty	57 03 25.01	26.24	209 48 54.45	25,826.11	7,871.73		
Reeves	49 42 39.70	39.11	340 08 27.10	22,636.14	6,899.43	46 13 36.79	111 25 37.74
Dougherty	55 11 50.34	49.75	209 48 54.45	25,826.11	7,871.73		
Reeves	45 32 07.31	06.09	75 23 12.36	21,583.80	6,578.68		
Howard	79 16 05.95	04.16	334 35 42.17	18,759.68	5,717.90	46 12 42.93	111 30 34.69
Howard	72 00 39.32	39.06	255 19 37.98	21,583.80	6,578.68		
Reeves	47 24 36.59	36.53	122 47 48.92	23,568.18	7,183.51		
Hossfeld	60 34 44.90	44.41	3 19 09.74	18,243.10	5,560.45	46 15 42.71	111 30 19.67
Reeves	50 35 43.39	43.96	122 47 48.92	23,568.18	7,183.51		
Hossfeld	80 26 39.67	40.37	222 17 44.88	24,144.09	7,359.05		
Deep Creek	48 57 34.66	35.67	353 22 56.43	30,813.61	9,391.90	46 18 38.94	111 26 28.25
Hossfeld	56 54 52.84	53.17	222 17 44.88	24,144.09	7,359.05		
Deep Creek	71 55 37.34	37.68	114 16 09.87	25,972.37	7,916.31		
Bridge	51 09 29.17	29.15	345 21 35.04	29,469.11	8,982.10	46 20 24.18	111 32 05.67
Deep Creek	64 50 19.58	19.47	114 16 09.87	25,972.37	7,916.31		
Bridge	70 22 36.18	35.91	223 49 29.87	33,370.84	10,171.34		
Marks	44 47 04.85	04.62	359 06 23.83	34,727.98	10,584.99	46 24 21.71	111 26 35.96
Bridge	56 28 54.86	53.54	223 49 29.87	33,370.84	10,171.34		
Marks	63 56 08.51	08.96	107 49 37.55	32,262.07	9,833.39		
Reed	59 34 58.70	57.50	347 19 17.54	34,761.70	10,595.27	46 25 58.97	111 33 54.40
Marks	52 43 53.61	53.59	107 49 37.55	32,262.07	9,833.39		
Reed	36 10 07.38	07.74	251 34 12.18	25,679.01	7,826.89		
Duck Creek	91 05 58.53	58.67	340 32 25.59	19,043.50	5,804.40	46 27 18.96	111 28 06.48
Duck Creek	72 27 23.99	24.02	71 38 24.30	25,679.01	7,826.89		
Reed	47 31 44.94	45.02	204 02 27.12	28,268.41	8,616.13		
Confederate	60 00 51.01	50.96	324 03 35.45	21,868.50	6,665.46	46 30 13.77	111 31 09.79
Reed	37 24 55.82	55.39	204 02 27.12	28,268.41	8,616.13		
Confederate	43 04 01.35	02.05	67 08 28.53	17,415.22	5,308.11		
Beaver Creek	99 31 02.34	02.56	346 36 44.81	19,572.67	5,965.69	46 29 06.93	111 34 59.09

TABLE I.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	Feet.	Metres.	° ′ ″	° ′ ″
Beaver Creek	93 15 45.88	45.98	247 05 42.23	17,415.22	5,308.11		
Confederate	42 36 41.57	41.27	109 45 09.82	24,972.86	7,611.66		
Squires	44 07 32.49	32.75	333 48 38.75	16,934.65	5,161.63	46 31 36.95	111 36 45.88
Confederate	56 35 48.59	49.08	109 45 09.82	24,972.86	7,611.66		
Squires	46 41 11.98	11.63	242 59 54.32	21,420.84	6,529.01		
Geary	76 42 59.03	59.29	346 20 13.19	18,670.07	5,690.58	46 33 12.86	111 32 12.83
Geary	82 33 40.18	40.46	63 03 12.51	21,420.84	6,529.01		
Squires	55 19 05.10	05.44	187 40 48.84	31,669.55	9,652.79		
Blackwell	42 07 14.52	14.10	325 34 18.71	26,263.70	8,005.10	46 36 46.75	111 35 45.27
Squires	45 59 48.67	47.80	187 40 48.84	31,669.55	9,652.79		
Blackwell	49 10 13.05	14.26	56 51 47.16	22,872.74	6,971.55		
Degan	84 49 57.16	57.94	321 38 25.98	24,060.87	7,333.69	46 34 43.24	111 40 19.41
Blackwell	84 27 10.84	09.72	56 51 47.16	22,872.74	6,971.55		
Degan	54 36 47.62	46.21	182 11 41.74	34,746.30	10,590.58		
Maxwell	40 56 04.20	04.07	321 15 51.49	28,460.47	8,674.67	46 40 25.96	111 40 00.33
Degan	37 05 31.87	30.50	182 11 41.74	34,746.30	10,590.58		
Maxwell	58 08 23.15	24.46	60 20 20.12	21,042.86	6,413.81		
Canyon Ferry	84 46 04.70	05.04	325 03 14.63	29,634.94	9,032.65	46 38 43.09	111 44 22.38
Maxwell	41 12 05.10	03.63	60 20 20.12	21,042.86	6,413.81		
Canyon Ferry	75 19 04.04	03.48	164 58 06.04	15,490.79	4,721.55		
Fuller	63 28 53.54	52.89	281 28 31.21	22,749.19	6,933.89	46 41 10.76	111 45 20.00
Canyon Ferry	63 41 43.78	43.74	164 58 06.04	15,490.79	4,721.55		
Fuller	83 43 02.46	02.02	68 40 26.18	25,783.70	7,858.80		
Stubbs	32 35 14.71	14.24	281 11 30.00	28,589.84	8,713.95	46 39 38.06	111 51 04.31
Fuller	76 23 36.26	37.46	68 40 26.18	25,783.70	7,858.80		
Stubbs	50 27 37.80	39.04	198 08 36.64	31,318.83	9,545.89		
El Dorado	53 08 43.57	43.50	325 01 34.99	24,850.17	7,574.26	46 44 31.80	111 48 44.29
Stubbs	42 45 59.48	58.60	198 08 36.64	31,318.83	9,545.89		
El Dorado	49 24 06.67	05.05	67 34 23.63	21,280.92	6,486.36		
Prickly Pear	87 49 58.83	56.35	335 20 54.48	23,797.02	7,253.26	46 43 11.57	111 53 26.59
Prickly Pear	96 08 49.71	51.21	247 30 58.09	21,280.92	6,486.36		
El Dorado	41 05 52.54	53.04	108 40 16.70	31,167.89	9,499.89		
Hilger	42 45 14.28	15.75	331 20 23.55	20,606.71	6,280.87	46 46 10.07	111 55 48.43
El Dorado	42 34 52.51	52.18	108 40 16.70	31,167.89	9,499.89		
Hilger	82 57 23.23	22.50	205 37 45.20	25,916.47	7,899.27		
American	54 27 46.54	45.32	331 11 57.33	38,013.13	11,586.30	46 50 00.68	111 53 07.21
Hilger	41 41 37.46	37.45	205 37 45.20	25,916.47	7,899.27		
American	108 00 49.89	50.50	133 40 33.28	34,175.15	10,416.49		
B. T. Mountain	30 17 32.79	32.05	343 53 45.70	48,861.11	14,892.73	46 53 53.48	111 59 03.10
American	47 02 58.95	58.32	133 40 33.28	34,175.15	10,416.49		
B. T. Mountain	74 42 04.43	03.59	238 54 09.92	29,416.40	8,966.04		
Willow Creek	58 14 57.11	58.09	0 43 36.84	38,765.38	11,815.58	46 56 23.28	111 53 00.14
B. T. Mountain	63 21 25.11	27.37	238 54 09.92	29,416.40	8,966.04		
Willow Creek	45 50 39.64	38.96	104 49 14.01	27,841.99	8,486.16		
Ox Bow	70 47 50.51	53.67	355 32 24.23	22,348.03	6,811.62	46 57 33.39	111 59 28.12
Willow Creek	46 22 04.23	03.55	104 49 14.01	27,841.99	8,486.16		
Ox Bow	55 12 37.63	36.85	229 31 53.63	20,570.00	6,269.68		
Mitler	78 25 20.05	19.60	331 09 19.00	23,340.18	7,114.02	46 59 45.10	111 55 42.40
Ox Bow	91 51 50.66	51.16	229 31 53.63	20,570.00	6,269.68		
Mitler	49 50 26.59	26.95	99 25 05.63	33,175.38	10,111.76		
Wolf Creek	38 17 42.01	41.89	317 37 02.21	25,367.90	7,732.06	47 00 38.41	112 03 34.61
Miller	38 56 21.31	21.30	99 25 05.63	33,175.38	10,111.76		
Wolf Creek	63 11 03.07	03.39	216 08 16.84	21,326.24	6,500.18		
Rock Creek	77 52 34.77	35.31	318 17 54.37	30,283.04	9,230.19	47 03 28.37	112 00 32.99
Mitler	41 47 22.22	21.43	138 21 26.98	30,283.04	9,230.19		
Rock Creek	71 38 25.72	24.77	246 39 29.55	21,993.80	6,703.65		
Wagner	66 34 14.15	13.80	0 08 49.31	31,324.23	9,547.54	47 04 54.28	111 55 41.24
Rock Creek	43 41 55.59	55.04	246 39 29.55	21,993.80	6,703.65		
Wagner	90 43 20.06	20.32	157 26 23.51	21,274.59	6,484.44		
Craig	45 34 45.10	44.64	22 59 41.71	30,791.83	9,385.26	47 08 08.17	111 57 39.28
Wagner	79 41 15.67	14.82	157 26 23.51	21,274.59	6,484.44		
Craig	51 40 08.49	08.66	285 44 48.34	27,885.12	8,499.30		
Stickney	48 38 37.49	36.52	57 10 56.10	22,233.41	6,776.68	47 06 53.30	111 51 11.28
Craig	53 18 19.19	19.20	285 44 48.34	27,885.12	8,499.30		
Stickney	39 41 17.53	16.86	145 30 49.55	22,389.61	6,824.29		
Sugar Loaf	87 00 24.64	23.94	52 28 59.06	17,831.95	5,435.13	47 09 55.40	111 54 14.73
Sugar Loaf	94 36 05.77	06.38	325 28 35.09	22,389.61	6,824.29		
Stickney	50 13 17.43	17.83	195 44 07.43	38,738.91	11,807.51		
Hardy	35 10 36.17	35.79	50 56 34.86	29,868.11	9,103.72	47 13 01.29	111 48 39.11
Stickney	45 39 01.46	00.22	195 44 07.43	38,738.91	11,807.51		
Hardy	71 57 36.52	36.15	307 48 22.78	31,261.44	9,528.40		
Sheep Creek	62 23 24.67	23.63	61 29 34.82	41,568.25	12,669.89	47 10 09.45	111 42 23.21
Hardy	77 31 32.28	31.53	303 48 22.78	31,261.44	9,528.40		
Sheep Creek	54 56 18.32	17.80	178 49 16.42	41,376.18	12,611.34		
Cascade	47 32 10.45	10.67	46 21 18.12	34,686.68	10,572.40	47 16 57.73	111 42 35.55
Sheep Creek	39 26 27.31	26.68	178 49 16.42	41,376.18	12,611.34		
Cascade	58 37 44.49	42.90	300 11 24.39	26,518.20	8,091.82		
St. Clair	81 55 53.01	50.42	38 19 38.14	35,680.70	10,875.38	47 14 45.84	111 37 03.99

TABLE I.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance. Feet.	Distance. Metres.	Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Cascade	73 34 41.17	40.81	300 11 24.39	26,548.20	8,091.82		
St. Clair	68 45 20.36	19.78	189 00 48.50	41,673.48	12,701.96		
Muddy Creek	37 39 58.59	59.41	46 41 57.67	40,493.36	12,342.27	47 21 32.05	111 35 28.17
St. Clair	37 20 27.91	28.52	189 00 48.50	41,673.48	12,701.96		
Muddy Creek	48 17 05.89	06.03	320 44 52.09	25,351.23	7,726.99		
Divide	94 22 25.35	25.45	46 25 17.68	31,198.61	9,509.25	47 18 18.23	111 31 35.45
Divide	78 29 30.94	30.58	140 47 43.20	25,351.23	7,726.99		
Muddy Creek	69 44 48.14	47.49	251 00 04.51	47,192.63	14,384.18		
Wilson	31 45 42.18	41.93	39 22 19.71	45,183.07	13,771.68	47 24 03.17	111 24 39.61
Muddy Creek	39 25 56.70	57.44	251 00 04.51	47,192.63	14,384.18		
Wilson	47 04 46.76	46.95	118 12 48.76	30,030.98	9,153.36		
Ulm	93 29 14.95	15.61	31 37 21.05	34,623.38	10,553.11	47 26 23.11	111 31 04.52
Ulm	30 27 00.37	26 59.50	298 08 05.35	30,030.98	9,153.36		
Wilson	46 30 27.32	27.86	164 43 16.65	15,622.16	4,761.59		
Antelope	103 02 32.69	32.64	87 45 05.23	22,363.39	6,816.30	47 26 31.90	111 25 39.49
Antelope	73 06 23.67	23.11	344 42 32.56	15,622.16	4,761.59		
Wilson	57 21 56.67	56.01	222 05 12.68	19,649.71	5,989.18		
Epler	49 31 40.73	40.88	91 39 14.63	17,293.88	5,271.13	47 26 27.04	111 21 28.03
Wilson	69 21 08.48	08.20	222 05 12.68	19,649.71	5,989.18		
Epler	77 22 05.71	05.88	324 45 27.80	33,509.57	10,213.62		
Big Bend	33 16 46.12	45.92	111 32 08.57	34,943.18	10,650.58	47 21 56.84	111 16 47.17
Big Bend	37 08 31.67	31.66	144 48 54.54	33,509.57	10,213.62		
Epler	45 20 29.93	30.11	279 24 57.65	20,408.24	6,220.37		
Sand Couleé	97 30 57.23	58.23	1 57 35.03	24,042.30	7,328.03	47 25 53.99	111 16 35.23
Epler	95 26 29.78	28.79	279 24 57.65	20,408.24	6,220.37		
Sand Couleé	32 39 01.60	02.10	132 07 35.42	25,814.00	7,868.03		
Sun River	51 54 30.18	29.11	3 58 39.24	13,990.13	4,264.15	47 28 44.79	111 21 13.92
Sand Couleé	63 16 18.94	19.54	132 07 35.42	25,814.00	7,868.03		
Sun River	55 26 16.34	16.75	256 37 53.32	26,287.59	8,012.38		
Great Falls	61 17 23.16	23.71	15 25 04.06	24,237.93	7,387.65	47 29 44.61	111 15 01.52
Sun River	56 35 52.87	52.45	256 37 53.32	26,287.59	8,012.38		
Great Falls	40 21 47.19	48.24	117 04 16.07	22,108.50	6,738.61		
Transfer	83 02 18.92	19.31	20 03 03.95	17,151.16	5,227.62	47 31 23.80	111 19 48.32
Transfer	35 23 31.78	31.62	297 00 44.61	22,108.50	6,738.61		
Great Falls	55 19 02.57	02.58	172 23 18.67	12,805.54	3,903.09		
North Great Falls	89 17 25.98	25.80	81 40 26.27	18,181.58	5,541.70	47 31 49.87	111 15 26.23
Great Falls	78 30 03.04	02.47	172 23 18.67	12,805.54	3,903.09		
North Great Falls	57 55 50.79	49.96	294 27 10.48	18,206.61	5,549.32		
Henry	43 34 08.89	07.57	70 56 00.91	15,744.47	4,798.87	47 30 35.42	111 11 24.85
North Great Falls	56 11 12.25	12.21	294 27 10.48	18,206.61	5,549.32		
Henry	75 03 30.92	31.74	189 33 40.26	20,118.69	6,132.12		
Porter	48 45 16.97	16.05	58 19 32.28	23,395.76	7,130.96	47 33 51.22	111 10 36.12
Henry	46 19 17.76	18.00	189 33 40.26	20,118.69	6,132.12		
Porter	51 12 42.24	41.09	318 21 35.09	14,677.02	4,473.51		
Bromedy	82 28 01.71	00.91	55 55 19.00	15,818.29	4,821.37	47 32 02.94	111 08 14.02
Porter	80 46 52.06	51.47	318 21 35.09	14,677.02	4,473.51		
Bromedy	55 38 58.07	57.92	194 02 17.87	21,019.58	6,406.71		
Earley	43 34 11.13	10.61	57 37 23.39	17,580.87	5,358.60	47 35 24.18	111 06 59.04
Bromedy	77 23 53.58	53.51	194 02 17.87	21,019.58	6,406.71		
Earley	59 49 04.28	03.39	314 14 09.33	30,200.17	9,204.93		
Belt	42 47 04.26	03.10	91 30 58.85	26,750.44	8,153.46	47 31 56.14	111 01 44.37
Belt	96 18 58.40	58.18	134 18 01.99	30,200.17	9,204.93		
Earley	40 39 43.91	44.59	273 34 24.67	43,995.43	13,409.68		
Shepherd	43 01 17.64	17.23	50 41 00.16	28,842.52	8,791.12	47 34 56.62	110 56 19.23
Earley	76 58 45.31	44.64	273 34 24.67	43,995.43	13,409.68		
Shepherd	31 54 34.98	34.45	125 36 51.99	45,303.65	13,808.43		
Portage	71 06 42.54	40.91	16 36 55.68	24,578.68	7,491.51	47 39 16.64	111 05 17.12
Shepherd	83 12 35.03	34.80	125 36 51.99	45,303.65	13,808.43		
Portage	36 19 40.24	39.89	269 10 34.69	51,705.88	15,759.81		
Highwood	60 27 45.21	45.31	28 52 07.34	30,847.12	9,402.11	47 39 23.28	110 52 42.02
Portage	55 07 29.65	29.14	269 10 34.69	51,705.88	15,759.81		
Highwood	59 09 05.33	05.19	148 28 58.11	46,534.09	14,183.46		
Sidney	65 43 26.30	25.67	34 08 00.58	48,696.88	14,842.67	47 45 54.63	110 58 38.04
Highwood	75 03 27.36	26.63	148 28 58.11	46,534.09	14,183.46		
Sidney	39 07 01.35	01.69	289 17 32.95	49,282.49	15,021.17		
Cherry	65 49 32.81	31.68	43 36 24.57	32,180.93	9,808.66	47 43 13.88	110 47 17.84
Sidney	40 19 12.81	11.86	289 17 32.95	49,282.49	15,021.17		
Cherry	56 54 26.50	25.98	166 20 22.44	32,143.75	9,797.32		
Tunis	82 46 23.95	22.16	69 05 22.39	41,618.91	12,685.33	47 48 21.61	110 49 09.03
Cherry	46 29 41.33	42.25	166 20 22.44	32,143.75	9,797.32		
Tunis	81 16 47.13	47.57	265 02 12.47	29,496.04	8,990.31		
Benton	52 13 29.75	30.18	32 54 01.15	40,196.44	12,251.76	47 48 46.57	110 41 58.56
Tunis	38 28 19.14	18.70	265 02 12.47	29,496.04	8,990.31		
Benton	82 42 10.85	10.45	167 49 41.90	21,447.57	6,537.16		
...ton	58 49 31.68	30.85	40 38 23.64	34,195.20	10,422.60	47 52 13.47	110 43 04.88

TABLE II.—*Tabulated results of secondary triangulation from Fort Benton to Trover Point, Mont.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	Feet.	Metres.	° ′ ″	° ′ ″
East base	38 54 17.63	18.27	73 01 05.7	9,869.05	3,008.06	47 50 40.25	110 40 04.27
West base	96 14 52.51	53.89	349 14 17.0	8,788.97	2,678.85	47 50 11.78	110 42 22.6[illegible]
Benton	44 50 47.21	47.84	214 05 22.7	13,911.32	4,240.13	47 48 46.57	110 41 58.56
East base	54 28 52.85	52.16	73 01 05.7	9,869.05	3,008.06		
West base	86 08 53.68	53.73	166 50 29.4	12,663.15	3,859.69		
Teton	39 22 14.80	14.11	307 27 44.0	15,522.99	4,731.36	47 52 13.47	110 43 04.88
East base	93 23 10.48	10.43	34 06 47.4	13,911.32	4,240.13		
Benton	46 15 40.72	40.81	167 49 41.9	21,447.57	6,537.16		
Teton	40 21 10.48	08.76	307 27 44.0	15,522.99	4,731.36	47 52 13.47	110 43 04.88
Benton	86 04 45.21	43.56	167 49 41.9	21,447.57	6,537.16		
Teton	47 26 14.64	14.47	300 22 38.2	29,506.12	8,993.40		
Shonkin	46 29 02.84	01.97	73 58 12.8	21,783.44	6,639.53	47 49 46.05	110 36 51.86
Teton	83 49 45.83	44.82	300 22 38.2	29,506.12	8,993.40		
Shonkin	87 07 12.15	13.34	207 34 28.1	19,153.67	5,837.99		
Crocon	59 03 00.26	01.84	86 39 06.5	34,361.25	10,473.21	47 52 33.58	110 34 41.82
Shonkin	39 31 18.86	18.00	207 34 28.1	19,153.67	5,837.99		
Crocon	43 08 57.59	56.77	344 27 07.7	12,289.21	3,745.72		
Harvey	97 19 46.11	45.23	67 07 58.2	13,207.09	4,025.48	47 50 36.73	110 33 53.53
Crocon	49 27 42.84	40.83	344 27 07.7	12,289.21	3,745.72		
Harvey	91 07 55.61	53.59	255 35 37.0	14,711.70	4,484.08		
Brulé	39 24 27.59	25.58	115 02 37.6	19,354.55	5,899.21	47 51 12.81	110 30 24.63
Crocon	71 39 52.11	50.89	294 59 26.9	19,354.55	5,899.21		
Brulé	45 05 44.09	42.88	160 08 20.4	20,575.35	6,271.31		
Tele	63 14 27.45	26.23	43 21 30.7	15,352.85	4,679.44	47 54 23.77	110 32 07.22
Brulé	58 53 00.25	00.00	160 08 20.4	20,575.55	6,271.31		
Tele	67 45 48.11	47.72	272 21 16.6	21,954.55	6,691.69		
Black Bluff	53 21 12.19	12.28	39 04 03.1	23,737.13	7,235.01	42 54 14.75	110 26 45.31
Tele	47 16 08.56	07.32	272 21 16.6	21,954.55	6,691.69		
Black Bluff	50 09 09.39	09.29	142 34 24.6	16,262.76	4,956.85		
Marias	82 34 44.61	43.39	45 07 20.5	16,998.07	5,180.97	47 56 22.17	110 29 10.45
Black Bluff	86 50 28.98	28.24	142 34 24.6	16,262.76	4,956.85		
Marias	56 18 46.99	46.36	266 13 50.0	27,078.53	8,253.46		
Three Islands	36 50 45.48	44.90	49 27 59.6	22,565.79	6,877.99	47 56 39.54	110 23 33.62
Marias	51 45 51.96	53.04	266 13 50.0	27,078.53	8,253.46		
Three Islands	53 00 33.87	34.24	139 19 18.8	21,996.73	6,704.54		
Ridge	75 13 31.34	32.72	34 30 15.1	22,368.10	6,817.74	47 59 24.12	110 26 04.38
Three Islands	62 52 14.21	14.36	139 19 18.8	21,996.73	6,704.54		
Ridge	68 34 02.52	02.28	250 42 40.1	26,113.49	7,959.32		
Recess	48 33 44.37	43.36	22 13 25.9	27,312.64	8,324.82	48 00 49.09	110 20 01.91
Three Islands	33 50 25.04	23.20	202 11 33.2	27,312.64	8,324.82		
Recess	58 08 37.13	35.71	324 04 50.1	15,218.72	4,638.62		
Mound	88 01 03.84	01.09	56 05 26.6	23,212.44	7,075.09	47 58 47.44	110 17 50.70
Recess	78 17 38.38	39.41	324 04 50.1	15,218.72	4,638.62		
Mound	57 30 41.74	42.31	201 46 00.9	21,435.48	6,533.47		
Coal banks	44 02 37.97	38.28	65 50 15.1	18,495.60	5,637.41	48 02 03.88	110 15 53.74
Mound	38 00 47.37	46.32	201 46 09.9	21,435.48	6,533.47		
Coal banks	49 51 26.30	25.59	331 56 11.2	13,209.88	4,026.33		
Shanks	92 07 49.71	48.09	59 49 31.1	16,397.44	4,997.89	48 00 08.83	110 14 22.37
Coal banks	80 17 53.05	55.77	331 56 11.2	13,209.88	4,026.33		
Shanks	71 45 58.93	59.44	223 43 18.5	27,794.96	8,471.83		
Old	27 56 04.15	04.79	71 42 53.5	26,782.34	8,163.18	48 03 26.97	110 09 39.62
Shanks	60 15 33.14	31.79	223 43 18.5	27,794.96	8,471.83		
Old	53 19 47.74	47.11	350 27 01.6	26,334.04	8,026.54		
Iron	66 24 41.16	41.10	104 03 08.2	24,326.61	7,414.68	47 59 10.69	110 08 35.41
Old	39 39 45.04	45.01	350 27 01.6	26,334.04	8,026.54		
Iron	69 42 29.71	29.45	240 10 18.7	17,816.59	5,430.45		
Sandy	70 37 46.81	45.54	130 50 53.3	26,181.80	7,980.14	48 00 38.09	110 04 48.12
Iron	58 30 58.86	31 00.30	240 10 18.7	17,816.59	5,430.45		
Sandy	73 41 34.80	36.67	346 31 31.1	20,513.22	6,252.37		
Burned	47 47 23.65	23.03	118 45 00.0	23,086.55	7,036.72	47 57 21.22	110 03 37.[illegible]
Iron	32 52 39.78	40.62	298 41 19.0	23,086.55	7,036.72		
Burned	74 02 08.12	08.68	44 42 51.4	13,099.15	3,902.58		
White Cliffs	73 05 08.66	10.70	151 36 00.3	23,199.71	7,071.21	47 55 49.34	110 05 53.[illegible]
Burned	52 18 06.90	06.57	44 42 51.4	13,099.15	3,992.58		
White Cliffs	93 12 33.48	33.27	317 53 44.3	18,303.98	5,579.00		
Castle	34 29 20.31	20.16	172 25 18.0	23,096.92	7,039.88	47 53 35.28	110 02 53.
Burned	34 22 18.71	18.41	352 24 44.8	23,096.92	7,039.88		
Castle	51 50 06.03	05.89	120 35 12.0	13,068.20	3,983.15		
Wellman	93 47 35.57	35.70	206 45 33.8	18,199.46	5,547.14	47 54 40.87	110.05 38.[illegible]
Castle	70 45 53.52	53.28	120 35 12.0	13,068.20	3,983.15		
Wellman	58 41 26.19	24.87	359 14 34.4	15,980.14	4,870.70		
Kipps	50 32 42.35	41.85	229 47 18.6	14,460.21	4,407.43	47 52 03.18	110.05 35.[illegible]
Castle	54 36 57.18	58.62	49 49 18.8	14,460.21	4,407.43		
Kipps	76 14 39.92	40.87	306 01 59.5	15,588.10	4,751.21		
Citadel	49 08 21.13	20.51	175 12 37.0	18,571.33	5,660.49	47 50 32.65	110.02 30.

TABLE II.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Kipps	44 32 02.19	01.82	306 01 59.5	15,588.10	4,751.21		
Citadel	71 37 50.42	49.94	54 26 26.5	12,180.49	3,712.58		
La Barge	63 50 06.37	08.24	170 34 30.6	16,482.74	5,023.89	47 49 22.72	110.04 55.60
Citadel	83 42 07.40	07.39	54 26 26.5	12,180.49	3,712.58		
La Barge	71 49 53.28	52.72	306 14 31.6	29,232.30	8,909.92		
Wall	24 28 01.49	27 59.89	150 46 47.2	27,943.50	8,517.10	47 46 32.02	109 59 10.46
Citadel	28 55 07.84	07.94	330 44 19.1	27,943.50	8,517.10		
Wall	60 35 25.54	25.45	220 22 12.6	13,663.03	4,164.45		
Pinnacles	81 29 25.46	26.61	121 53 15.3	26,480.80	8,071.28	47 48 14.73	109 57 00.84
Wall	86 23 53.48	55.07	220 22 12.6	13,663.03	4,164.45		
Pinnacles	64 08 46.37	47.98	336 15 00.7	27,730.37	8,452.14		
Rondeau	29 27 15,25	16.95	126 49 44.7	25,004.30	7,621.24	47 44 04.21	109 54 17.48
Pinnacles	33 56 11.65	12.29	336 15 00.7	27,730.37	8,452.14		
Rondeau	77 27 35.30	33.36	233 44 34.9	16,627.11	5,067.90		
Pablos	68 36 17.38	14.35	122 23 14.5	29,072.41	8,861.19	47 45 41.21	109 51 01.26
Rondeau	36 49 38.51	39.16	223 44 34.9	16,627.11	5,067.90		
Pablos	80 39 18.39	19.74	333 07 40.4	11,234.24	3,424.16		
Tip Top	62 31 00.43	01.10	90 37 34.2	18,493.48	5,636.76	47 44 02.31	109 49 46.99
Rondeau	34 36 17.42	18.03	270 34 14.0	18,493.48	5,636.76		
Tip Top	108 59 07.27	06.60	341 38 27.6	17,694,55	5,393.25		
Arrow	36 24 36.06	35.37	125 14 52.5	29,462.18	8,979.99	47 41 16.56	109 48 25.54
Tip Top	55 51 40.23	41.44	341 38 27.6	17,694.55	5,393.25		
Arrow	70 36 06.74	08.25	232 15 36.1	18,210.50	5,550.51		
Plateau	53 32 09.12	10.31	105 50 22.2	20,752.88	6,325.42	47 43 06.51	109 44 54.96
Arrow	38 16 29.45	28.50	232 15 36.1	18,210.50	5,550.51		
Plateau	89 28 01.20	27 59.56	322 50 12.3	14,264.48	4,347.77		
Pines	52 15 34.34	31.94	90 36 13.5	23,027.40	7,018.69	47 41 14.31	109 42 49.03
Plateau	97 17 12.90	12.74	322 50 12.3	14,264.48	4,347.77		
Pines	42 19 29.36	29.70	185 11 15.1	21,836.52	6,655.71		
Valley	40 23 17.31	17.56	45 34 54.2	14,823.00	4,518.01	47 44 48.93	109 42 20.15
Pines	63 43 05.86	05.96	185 11 15.1	21,836.52	6,655.71		
Valley	58 29 25.31	25.97	306 42 10.5	23,140.20	7,053.07		
Judith	57 47 28.52	28.07	68 58 03.1	22,002.74	6,706.37	47 42 32.35	109 37 48.91
Valley	55 37 24.74	25.25	306 42 10.5	23,140.20	7,053.07		
Judith	76 14 10.99	10.15	202 59 41.3	25,643.35	7,816.02		
Council	48 08 24.91	24.60	71 09 54.4	30,177.69	9,198.08	47 46 25.29	109.35 22.22
Judith	52 40 39.42	39.45	202 59 41.3	25,643.35	7,816.02		
Council	64 39 34.11	34.26	318 21 55.6	22,956.24	6,997.00		
Holmes	62 39 45.89	46.29	75 44 54.4	26,089.59	7,952.03	47 43 35.91	109 31 39.21
Council	28 35 10.19	09.59	318 21 55.6	22,956.24	6,997.00		
Holmes	54 31 40.59	39.18	192 56 19.7	11,063.82	3,372.22		
Iron City	96 53 13.51	11.23	109 49 57.8	18,831.29	5,739.73	47 45 22.32	109 31 02.96
Holmes	60 59 42.17	42.20	192 56 19.7	11,063.82	3,372.22		
Iron City	87 16 43.01	43.03	285 40 03.5	18,400.53	5,608.43		
Bear	31 43 35.16	34.77	73 59 40.5	21,015.59	6,405.50	47 44 33.20	109 26 43.77
Holmes	36 53 15.86	15.61	253 56 01.9	21,015.59	6,405.50		
Bear	54 27 24.69	25.00	19 32 15.5	12,618.01	3,845.93		
Gallatin	88 39 18.93	19.39	110 52 10.5	17,104.65	5.213.45	47 42 35.84	109 27 45.47
Bear	95 40 57.42	55.99	19 32 15.5	12,618.01	3,845.93		
Gallatin	54 09 17.50	17.13	253 40 47.0	24,988.89	7,616.55		
Dauphin	30 09 46.54	46.88	103 54 53.4	20,356.07	6,204.47	47 43 44.99	109 21 54.71
Bear	44 11 20.15	17.70	283 51 19.5	20,356.07	6,204.47		
Dauphin	61 45 46.13	47.20	165 40 40.6	14,756.71	4,497.80		
Rapids	74 02 54.65	55.10	59 42 56.1	18,651.85	5,685.03	47 46 06.09	109 22 48.14
Dauphin	34 39 13.46	13.55	165 40 40.6	14,756.71	4,497.80		
Rapids	114 13 00.51	01.30	231 26 59.7	16,230.87	4,947.13		
Lone Pine	31 07 43.88	45.15	20 21 32.2	26,032.56	7,934.65	47 47 45.88	109 19 42.25
Dauphin	35 46 19.65	19.87	200 19 54.1	26,023.56	7,934.65		
Lone Pine	86 19 34.60	34.40	294 01 57.8	17,963.63	5,475.26		
Chimney	57 54 06.21	05.73	56 10 49.9	30,666.91	9,347.19	47 46 33.61	109 15 42.08
Lone Pine	32 25 46.46	46.70	294 01 57.8	17,963.63	5,475.26		
Chimney	118 43 23.29	23.17	232 48 18.8	19,966.18	6.085.64		
Windsor	28 50 49.72	50.13	81 42 01.5	32,650.73	9,951,85	47 48 32.66	109 11 49.10
Chimney	46 17 56.51	56.49	232 48 18.8	19,966.18	6.085.64		
Windsor	91 06 30.91	31.51	321 44 39.8	21,328.50	6.500.87		
Birds	42 35 31.01	32.00	99 11 30.9	29,496.37	8,990.41	47 45 47.33	109 08 35.83
Windsor	53 44 35.39	35.25	321 44 39.8	21,328.50	6,500.87		
Birds	83 13 57.07	56.69	225 00 59.6	25,206.54	7,682.88		
Sturgeon	43 01 26.71	28.06	88 05 41.5	31,041.32	9,461.31	47 48 43.10	109 04 14.66
Birds	37 13 51.69	51.70	225 00 59.6	25,206.54	7,682.88		
Sturgeon	69 23 34.25	34.27	335 40 38.7	15,915.91	4,851.12		
Spruce	73 22 35.12	34.03	82 19 15.8	24,622.86	7,504.98	47 46 19.96	109 02 38.70
Sturgeon	73 43 46.62	47.95	335 40 38.7	15,915.91	4,851.12		
Spruce	67 15 47.69	48.59	222 57 38.4	24,274.31	7,398.74		
Snake Point	39 00 22.94	23.46	82 01 01.4	23,322.00	7,108.48	47 49 15.20	108 58 36.32
Spruce	58 42 09.73	11.26	222 57 38.4	24,274.31	7,398.74		
Snake Point	54 10 29.68	29.77	348 50 08.1	22,513.03	6,861.91		
Cow Island	67 07 17.79	18.97	101 43 36.4	21,362.28	6,511.16	47 45 37.23	108 57 32.53

TABLE II.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Snake Point	31 15 37.59	39.43	348 50 08.1	22,513.03	6,861.91		
Cow Island	82 10 47.31	48.42	251 01 43.8	12,733.71	3,881.20		
Landing	66 33 31.05	32.15	137 37 26.4	24,309.90	7,409.59	47 46 18.05	108 54 36.27
Cow Island	73 32 52.97	52.27	251 01 43.8	12,733.71	3,881.20		
Landing	66 14 20.82	20.31	4 49 33.9	18,915.26	5,765.32		
Bend	40 12 48.31	47.42	144 36 29.2	18,051.00	5,501.89	47 43 12.03	108 54 59.54
Landing	58 09 04.66	05.21	4 49 33.9	18,915.26	5,765.32		
Bend	57 09 02.28	01.41	241 58 18.1	17,772.36	5,416.97		
Fortress	64 41 52.69	53.38	126 43 01.3	17,576.77	5,357.35	47 44 34.39	108 51 10.03
Bend	61 50 19.38	19.46	241 58 18.1	17,772.36	5,416.97		
Fortress	44 26 48.74	48.17	17 34 19.7	16,323.42	4,975.33		
Crystal	73 42 52.47	52.37	128 50 34.0	12,965.23	3,951.76	47 42 00.81	108 53 22.07
Fortress	67 14 24.54	24.60	17 34 19.7	16,323.42	4,975.33		
Crystal	70 06 53.80	53.50	267 40 19.9	22,219.02	6,772.29		
Grand Island	42 38 40.72	41.90	130 23 01.8	22,658.55	6,906.26	47 42 09.59	108 46 57.53
Crystal	42 19 01.04	02.15	267 40 19.9	22,219.02	6,772.29		
Grand Island	55 39 19.61	19.56	82 05 00.3	15,104.58	4,603.83		
Quarter	82 01 38.26	38.29	130 01 55.4	18,524.40	5,646.19	47 40 03.27	108 48 54.73
Grand Island	77 41 33.22	33.49	82 05 00.3	15,104.58	4,603.83		
Quarter	51 34 27.59	26.73	263 38 00.4	19,061.29	5,809.83		
Willow	50 43 58.09	59.78	134 25 24.8	15,284.11	4,658.55	47 40 24.04	108 44 17.96
Quarter	38 25 20.65	19.60	263 38 00.4	19,061.29	5,809.83		
Willow	87 36 25.48	26.19	356 04 58.8	14,647.44	4,464.50		
Calf Island	53 58 14.60	14.21	122 06 55.4	23,549.29	7,177.76	47 37 59.32	108 44 03.36
Willow	55 36 37.52	37.63	356 04 58.8	14,647.44	4,464.50		
Calf Island	71 31 54.62	54.58	247 37 04.1	15,163.32	4,621.74		
Buffalo	52 51 27.94	27.79	120 31 03.2	17,428.65	5,312.29	47 38 56.75	108 40 38.60
Calf Island	46 52 06.46	06.83	247 37 04.1	15,163.32	4,621.74		
Buffalo	91 55 12.61	13.11	335 44 22.3	16,796.26	5,119.45		
Armel	41 12 39.17	40.06	114 32 56.6	23,002.41	7,011.07	47 36 25.62	108 38 57.90
Buffalo	51 16 28.90	28.54	335 44 22.3	16,796.26	5,119.45		
Armel	72 47 10.25	10.80	228 32 47.5	15,817.17	4,821.03		
Harriet	55 56 21.62	20.66	104 31 16.0	19,366.30	5,902.79	47 38 08.92	108 36 04.82
Armel	52 53 27.41	29.32	228 32 47.5	15,817.17	4,821.03		
Harriet	48 28 07.70	07.65	0 06 47.6	12,866.14	3,921.56		
Brevier	78 38 21.26	23.03	101 28 24.3	12,077.26	3,681.12	47 36 01.95	108 36 05.20
Harriet	82 00 36.02	36.70	0 06 47.6	12,866.14	3,921.56		
Brevier	71 38 44.11	44.73	251 45 32.1	28,711.91	8,751.31		
Creek	26 20 37.66	38.57	98 11 04.7	27,518.39	8,387.53	47 37 30.45	108 29 27.15
Brevier	28 14 05.74	05.22	251 45 32.1	28,711.91	8,751.31		
Creek	91 02 34.38	33.17	340 47 52.9	15,572.32	4,746.40		
Rocky Point	60 43 24.15	21.61	100 05 26.4	32,911.12	10,031.22	47 35 05.31	108 28 12.45
Creek	52 46 48.96	50.20	340 47 52.9	15,572.32	4,746.40		
Rocky Point	78 46 31.82	31.39	239 35 19.4	16,571.52	5,050.95		
Autumn	48 26 36.81	38.41	108 04 31.8	20,411.92	6,221.50	47 36 28.04	108 24 43.91
Rocky Point	44 47 28.61	28.85	239 35 19.4	16,571.52	5,050.95		
Autumn	37 26 05.11	06.14	22 11 47.2	11,783.33	3,591.53		
Lopp	97 46 23.97	25.01	104 24 34.3	10,166.62	3,098.76	47 34 40.37	108 25 48.83
Autumn	61 09 38.25	38.03	22 11 47.2	11,783.33	3,591.53		
Lopp	87 39 22.87	22.34	289 50 21.6	19,935.00	6,076.18		
Carroll	31 10 59.62	59.63	141 04 43.1	22,738.46	6,930.62	47 33 33.51	108 21 15.46
Autumn	33 16 24.02	23.83	321 02 09.2	22,738.46	6,930.62		
Carroll	56 58 20.01	19.34	198 03 02.4	12,475.15	3,802.39		
Ryan	89 45 18.01	16.83	107 49 00.8	19,064.21	5,810.72	47 35 30.56	108 20 19.07
Carroll	61 43 18.97	18.80	198 03 02.4	12,475.15	3,802.39		
Ryan	80 59 39.74	39.40	297 04 04.6	18,136.29	5,527.89		
Ryan Island	37 17 01.26	01.80	79 49 56.6	20,340.15	6,199.62	47 34 09.05	108 16 23.59
Ryan	32 44 34.64	35.69	297 04 04.6	18,136.29	5,527.89		
Ryan Island	70 30 13.51	14.91	187 37 13.3	10,077.61	3,071.63		
Plain	76 45 07.32	09.40	84 22 37.1	17,563.84	5,353.41	47 35 47.63	108 16 04.09
Ryan Island	88 52 42.00	41.11	187 37 13.3	10,077.61	3,071.63		
Plain	58 38 36.76	36.13	308 58 51.5	18,763.46	5,719.05		
Sage	32 28 42.42	42.76	96 32 45.8	16,026.03	4,884.69	47 33 51.08	108 12 31.44
Plain	36 02 47.44	46.97	308 58 51.5	18,763.46	5,719.05		
Sage	94 39 32.55	33.01	223 41 01.5	14,564.80	4,439.31		
Kannuck	49 17 39.82	40.02	93 00 29.9	24,669.80	7,519.28	47 35 35.00	108 10 04.69
Sage	46 15 19.42	19.08	223 41 01.5	14,564.80	4,439.31		
Kannuck	85 40 40.35	38.79	318 02 11.1	14,143.82	4,311.00		
Line	48 04 02.43	02.13	89 59 50.7	19,522.51	5,950.41	47 33 51.19	108 07 46.80
Kannuck	36 55 10.15	10.38	318 02 11.1	14,143.82	4,311.00		
Line	88 43 26.49	27.11	226 47 20.0	10,454.72	3,186.57		
Across	54 21 25.66	22.51	101 10 04.6	17,400.10	5,303.50	47 35 01.82	108 05 55.67
Kannuck	42 42 10.49	12.04	281 07 00.7	17,400.10	5,303.50		
Across	79 36 31.20	30.50	180 46 35.1	13,962.92	4,255.86		
Hawley	57 41 14.21	17.46	58 27 54.5	20,250.46	6,172.28	47 37 19.61	108 05 52.90
Across	76 16 24.97	26.19	180 46 35.1	13,962.92	4,255.86		
Hawley	61 55 16.24	16.79	298 51 20.2	20,348.39	6,202.18		
Frost	41 48 17.38	17.02	77 06 15.1	18,481.23	5,633.08	47 35 42.61	108 01 32.91

TABLE II.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Across	31 20 20.80	22.77	257 03 01.1	18,481.23	5,633.03		
Frost	92 14 36.66	36.80	344 51 38.3	11,538.17	3,516.80		
Slide	56 24 58.50	25 00.43	108 27 10.3	22,167.13	6,756.48	47 33 52.69	108 00 48.98
Frost	63 36 18.45	19.05	344 51 38.3	11,538.17	3,516.80		
Slide	82 20 43.04	43.41	247 12 54.1	18,459.01	5,626.25		
Lake	34 02 56.69	57.54	101 18 54.9	20,423.63	6,225.07	47 35 03.16	107 56 40.76
Slide	35 58 48.63	49.85	247 12 54.1	18,459.01	5,626.25		
Lake	43 13 15.39	15.41	24 02 41.9	11,040.33	3,365.06		
Pike	100 47 54.24	54.74	103 13 58.8	12,868.86	3,922.39	47 33 23.66	107 57 46.33
Lake	81 46 56.26	56.04	24 02 41.9	11,040.33	3,365.06		
Pike	46 55 22.86	22.21	250 57 15.7	14,002.15	4,267.82		
Cut-off	51 17 41.22	41.75	122 17 19.9	10,333.76	3,149.70	47 34 06.71	107 54 33.34
Pike	48 50 20.67	20.43	250 57 15.7	14,002.15	4,267.82		
Cut-off	74 56 10.69	11.32	356 03 26.8	12,682.14	3,865.48		
Above	56 13 27.85	28.25	119 50 07.9	16,266.43	4,957.96	47 32 03.84	107 54 20.64
Cut-off	56 27 37.95	38.43	356 03 26.8	12,682.14	3,865.48		
Above	81 03 27.65	28.22	257 07 04.4	15,652.02	4,770.69		
Hornets	42 28 52.94	52.35	119 38 41.8	18,550.27	5,654.07	47 32 38.22	107 50 38.27
Above	41 46 13.31	14.43	257 07 04.4	15,652.02	4,770.69		
Hornets	84 31 38.51	38.86	352 38 09.5	12,937.04	3,943.17		
Below	53 42 05.69	06.71	118 56 20.6	19,332.12	5,892.38	47 30 31.59	107 50 14.12
Hornets	29 39 34.76	35.22	352 38 09.5	12,937.04	3,943.17		
Below	86 38 30.19	30.88	259 16 58.2	7,141.17	2,176.61		
Nest	63 41 53.32	53.90	143 00 07.5	14,406.23	4,390.98	47 30 44.69	107 48 31.92
Hornets	83 03 24.19	25.73	322 58 34.3	14,406.23	4,390.98		
Nest	54 10 30.58	32.00	197 10 39.5	21,060.52	6,419.19		
Wilson	42 46 01.52	02.27	59 57 48.7	17,202.34	5,243.22	47 34 03.26	107 47 01.22
Nest	36 12 09.40	08.13	197 10 39.5	21,060.52	6,419.19		
Wilson	84 51 41.19	40.74	292 20 05.6	14,521.57	4,426.13		
Track	58 56 12.58	11.13	53 26 19.0	24,487.50	7,463.72	47 33 08.75	107 43 45.43
Wilson	69 57 22.07	23.56	292 20 05.6	14,521.57	4,426.13		
Track	64 23 52.91	53.79	176 46 23.9	19,079.07	5,815.25		
Elk	45 38 42.62	42.65	42 24 55.0	18,315.17	5,582.41	47 36 16.75	107 44 01.10
Track	38 29 53.95	54.02	176 46 23.9	19,079.07	5,815.25		
Elk	79 11 51.74	51.83	277 34 20.5	13,413.37	4,088.36		
Horn	62 18 13.62	14.15	35 18 29.6	21,166.08	6,451.36	47 35 59.26	107 40 47.11
Elk	53 09 53.67	53.88	277 34 20.5	13,413.37	4,088.36		
Horn	95 09 10.20	09.53	192 45 53.3	20,440.49	6,230.20		
Forgey	31 40 57.26	56.59	44 27 38.6	25,435.77	7,752.75	47 39 16.00	107 39 41.14
Horn	54 09 56.36	56.46	192 45 53.3	20,440.49	6,230.20		
Forgey	47 46 57.60	58.63	321 59 43.3	16,938.32	5,162.75		
Trovers	78 03 04.29	04.91	66 58 23.2	15,473.58	4,716.30	47 36 59.04	107 37 19.34
Elk	49 57 52.81	55.31	277 34 20.5	13,413.37	4,088.36		
Horn	66 39 45.11	46.73	164 16 30.5	11,488.55	3,501.68		
West Base	63 22 16.13	17.96	47 38 14.9	13,777.31	4,199.29	47 37 48.39	107 41 32.56
Horn	39 02 35.41	34.84	164 16 30.5	11,488.55	3,501.68		
West Base	92 46 45.27	46.63	251 29 10.2	9,710.86	2,959.84		
East Base	48 10 37.82	38.53	23 20 11.0	15,398.34	4,693.37	47 38 18.80	107 39 18.11

EXTRA STATIONS.

At Benton:							
East Base	89 54 —	10	73 01 05.7	9,869.05	3,008.06		
West Base	11 04 —	25	264 03 48	10,052.95	3,064.11		
Hub	79 01 —	25	163 07 02	1,930.87	588.52	47 50 22.02	110 39 56.05
Hub	43 14 —	20	84 05 37	10,052.95	3,064.11		
West Base	85 10 —	30	349 14 17	8,788.97	2,678.85		
Benton	51 35 —	10	220 49 45	12,784.65	3,896.73		
Hub	43 54 —	05	40 51 17	12,784.65	3,896.73		
Benton	37 48 —	15	258 38 00	8,958.83	2,730.63		
Flagstaff, Fort Benton	98 17 —	40	176 57 16	7,919.37	2,413.80	47 49 03.97	110 39 49.88
At Musselshell:							
Above	82 49 —	24.16	298 53 18.8	19,332.12	5,892.38		
Below	36 06 —	49.73	82 49 30.9	21,917.00	6,680.24		
Raid	61 03 —	46.11	201 41 51.2	13,019.69	3,968.36	47 30 04.46	107 55 30.78
Above	76 37 —	32.01	298 53 18.8	19,332.12	5,892.38		
Below	56 57 —	49.29	61 58 31.3	25,966.85	7,914.62		
Cowboy	46 24 —	38.70	195 29 46.6	22,375.51	6,819.99	47 28 31.05	107 55 47.75
Above	29 06 —	03.90	298 53 18.8	19,332.12	5,892.38		
Below	66 08 —	49.75	52 47 30.9	9,441.80	2,877.83		
Williams	84 45 —	06.35	148 01 03.8	17,755.34	5,411.78	47 29 35.23	107 52 03.60
Above	60 39 —	13.63	298 53 18.8	19,332.12	5,892.38		
Below	85 40 —	14.82	33 16 05.3	30,390.78	9,263.03		
Musselshell	33 40 —	31.55	179 32 35.4	34,765.37	10,596.39	47 26 20.74	107 54 16.60

TABLE III.—*Tabulated results of secondary triangulation from Trover Point, Mont., to Fort Buford, N. Dak.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first, in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	″	° ′ ″	Feet.	Metres.	° ′ ″	° ′ ″
Horn	73 33 33.34	36.14	192 45 53.30	20,440.43	6,230.19		
Forgey	71 42 24.10	24.86	301 04 17.01	34,409.18	10,487.82		
Dog Town	34 43 58.59	59.00	86 25 35.71	34,062.86	10,382.27	47 36 20.51	107 32 31.11
Forgey	33 22 12.10	11.85	301 04 17.01	34,409.18	10,487.82		
Dog Town	77 23 40.04	41.76	198 33 16.47	20,241.36	6,169.51		
Ball Rock	69 14 03.38	06.38	87 48 32.51	35,912.61	10,946.07	47 39 29.88	107 30 57.03
Dog Town	51 51 51.24	49.19	198 33 16.47	20,241.36	6,169.51		
Ball Rock	99 02 46.78	44.81	279 31 41.16	32,745.78	9,980.82		
7 Black Feet	29 05 25.94	26.00	70 32 03.48	41,114.72	12,531.65	47 38 36.12	107 23 05.48
Ball Rock	51 29 01.72	01.26	279 31 41.16	32,745.78	9,980.82		
7 Black Feet	67 40 22.08	22.91	167 17 52.77	29,338.85	8,942.40		
Rock Peak	60 50 36.68	35.83	48 07 18.86	34,685.90	10,572.17	47 43 18.56	107 24 39.62
7 Black Feet	76 57 33.03	32.27	167 17 52.77	29,338.85	8,942.40		
Rock Peak	71 36 40.33	39.84	275 40 02.66	54,812.23	16,706.61		
3 Cañon	31 25 48.17	47.89	64 24 04.66	53,390.36	16,273.23	47 42 24.37	107 11 22.41
7 Black Feet	28 58 46.52	45.74	244 15 24.87	53,390.36	16,273.23		
3 Cañon	53 52 41.24	41.92	10 31 22.74	26,069.66	7,945.96		
Gibson	97 08 31.88	32.34	93 21 59.02	43,464.21	13,247.77	47 38 11.41	107 12 31.92
3 Cañon	65 20 14.06	13.00	10 31 22.74	26,069.66	7,545.96		
Gibson	75 53 06.73	04.32	266 23 35.90	37,827.04	11,529.58		
Little Snow	38 46 43.92	42.68	125 17 05.88	40,367.32	12,303.85	47 38 34.53	107 03 20.67
3 Cañon	31 57 45.97	46.45	305 11 09.74	40,367.32	12,303.85		
Little Snow	86 32 41.93	42.09	211 49 47.97	24,317.77	7,411.99		
Grizzly	61 29 30.91	31.47	93 21 38.03	45,853.66	13,976.07	47 41 58.38	107 00 13.20
Little Snow	47 45 59.64	57.82	211 49 47.97	24,317.77	7,411.99		
Grizzly	96 05 14.04	12.97	295 46 53.60	30,524.31	9,303.72		
Hell Creek	36 08 49.59	49.21	79 43 01.24	40,993.99	12,494.85	47 39 47.17	106 53 31.71
Grizzly	68 21 38.74	39.76	295 46 53.60	30,524.31	9,303.72		
Hell Creek	70 46 15.00	16.01	186 38 06.46	43,363.01	13,216.92		
5 Pines	40 52 03.19	04.23	47 31 04.89	44,048.05	13,425.72	47 46 52.24	106 52 18.35
Hell Creek	29 18 09.20	09.15	186 38 06.46	43,363.01	13,216.92		
5 Pines	21 58 30.20	31.37	344 40 29.29	27,202.11	8,291.12		
Featherland	128 43 18.36	19.48	35 58 27.57	20,798.53	6,339.83	47 42 33.32	106 50 33.24
5 Pines	58 43 26.45	25.30	344 40 29.29	27,202.11	8,291.12		
Featherland	87 53 34.46	33.89	252 35 20.97	42,252.24	12,878.36		
Norris	33 23 00.90	00.81	106 05 38.46	49,403.26	15,057.98	47 44 37.67	106 40 43.43
5 Pines	37 09 24.14	21.90	285 57 03.99	49,403.26	15,057.98		
Norris	68 18 19.58	19.78	174 23 58.24	30,959.46	9,436.36		
Double Hill	74 32 19.70	18.32	68 55 43.77	47,627.59	14,516.76	47 49 41.74	106 41 27.69
Norris	56 26 11.80	12.06	174 23 58.24	30,959.46	9,436.36		
Double Hill	92 44 30.77	30.74	261 38 51.71	50,350.42	15,346.67		
Last Pine	30 49 16.25	17.20	50 58 38.79	60,355.52	18,396.19	47 50 53.27	106 29 17.45
Double Hill	31 46 02.89	02.10	261 38 54.71	50,350.42	15,346.67		
Last Pine	48 24 40.23	39.67	130 12 35.61	26,902.30	8,199.74		
Juniper	99 49 20.07	18.23	49 58 10.29	38,218.53	11,648.90	47 53 44.55	106 34 18.87
Last Pine	87 28 44.82	42.85	130 12 35.61	26,902.30	8,199.74		
Juniper	60 44 10.95	10.17	249 24 41.89	51,024.02	15,551.98		
Dry Fork	31 47 08.08	06.98	37 46 15.54	44,555.37	13,580.35	47 56 41.03	106 22 37.37
Juniper	59 31 06.15	06.83	249 24 41.89	51,024.02	15,551.98		
Dry Fork	47 59 53.78	53.49	117 33 16.06	46,110.41	14,054.33		
Peck	72 28 59.48	59.68	9 54 49.28	39,760.92	12,119.02	48 00 11.09	106 32 38.43
Dry Fork	47 14 58.97	58.99	117 33 16.06	46,110.41	14,054.33		
Peck	76 53 11.41	09.99	220 32 39.61	40,907.78	12,468.58		
Galpin	55 51 52.37	51.02	344 45 39.38	54,255.61	16,536.96	48 05 17.67	106 26 06.81
Galpin	39 20 01.66	01.51	344 45 39.88	54,255.61	16,536.96		
Dry Fork	41 43 59.76	59.89	206 32 15.32	34,811.43	10,610.43		
Milk River	98 55 58.73	58.61	125 31 03.91	36,559.49	11,143.23	48 01 48.81	106 18 48.58
Galpin	38 57 22.60	21.72	305 25 37.95	36,559.49	11,143.23		
Milk River	58 51 20.94	20.45	184 22 24.86	23,201.13	7,071.64		
Nassau	82 11 16.90	17.83	86 34 01.75	31,583.16	9,626.46	48 05 36.59	106 18 23.5
Milk River	70 01 51.19	49.43	184 22 24.36	23,201.13	7,071.64		
Nassau	75 43 34.12	32.83	288 30 10.77	38,751.61	11,811.38		
Kintyre	34 14 37.65	37.74	74 31 15.10	39,957.72	12,179.00	48 03 33.98	106 09 22.09
Milk River	35 06 30.14	31.21	254 24 13.85	39,957.72	12,179.00		
Kintyre	68 56 29.15	29.75	5 34 45.35	23,689.59	7,220.52		
Bone Bluffs	75 56 57.39	59.03	109 37 21.15	38,439.12	11,716.13	47 59 41.26	106 09 55.9
Kintyre	101 57 04.87	05.56	5 34 45.35	23,689.59	7,220.52		
Bone Bluffs	47 32 07.22	06.45	233 06 26.03	45,645.66	13,912.67		
Lennox	30 30 45.49	47.99	83 43 54.19	34,418.50	10,490.66	48 04 11.82	106 00 58.5

TABLE III.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	Feet.	Metres.	° ′ ″	° ′ ″
Bone Bluffs	41 50 00.81	00.11	233 06 26.63	45,645.66	13,912.67		
Lennox	71 53 42.08	42.57	341 19 23.59	33,255.49	10,136.18		
Amelia Poe	66 16 19.17	17.32	95 05 02.63	47,392.14	14,445.00	47 59 00.40	105 58 22.00
Lennox	59 02 19.63	19.86	341 19 23.59	33,255.49	10,136.18		
Amelia Poe	38 18 09.01	09.79	199 39 29.74	28,752.84	8,763.79		
Santee	82 39 30.97	30.35	102 20 45.91	20,782.67	6,334.50	48 03 27.58	105 55 59.62
Amelia Poe	59 47 11.30	11.68	199 39 29.74	28,752.84	8,763.79		
Santee	83 15 32.63	31.64	296 25 43.87	41,330.20	12,597.33		
Elk River	36 57 17.47	16.68	79 35 11.58	47,496.50	14,476.80	48 00 25.69	105 46 55.42
Santee	43 11 59.14	59.66	296 25 43.87	41,330.20	12,597.33		
Elk River	26 03 01.77	02.52	142 35 31.15	30,254.76	9,221.57		
Oswego	110 44 57.30	57.81	73 16 57.65	19,409.77	5,916.04	48 04 22.75	105 51 26.01
Elk River	110 01 49.70	52.69	142 35 31.15	30,254.76	9,221.57		
Oswego	37 55 21.83	24.39	284 36 35.45	53,571.64	16,328.48		
Hopkins	32 02 44.96	42.92	72 43 29.69	35,045.62	10,681.81	48 02 08.68	105 38 43.35
Elk River	66 31 26.10	25.82	142 35 31.15	30,254.76	9,221.57		
Oswego	70 28 38.02	36.90	252 03 22.94	40,690.49	12,402.35		
Wolf Point	42 59 57.30	57.28	29 10 39.90	41,812.03	12,744.19	48 06 26.05	105 41 55.68
Wolf Point	76 29 25.42	25.23	333 22 23.39	29,169.89	8,890.90		
Hopkins	70 51 09.32	07.92	224 15 54.52	52,561.10	16,020.48		
Macon	32 39 23.67	26.85	77 02 03.80	51,066.16	15,564.82	48 08 19.77	105 29 42.52
Hopkins	34 24 36.76	37.11	224 15 54.52	52,561.10	16,020.48		
Macon	60 14 37.32	38.49	344 07 58.35	29,801.39	9,083.38		
Spread Eagle	85 20 44.95	44.40	78 48 43.21	45,781.73	13,954.14	48 03 36.87	105 27 32.59
Spread Eagle	75 08 04.42	03.89	164 09 27.61	29,801.39	9,083.38		
Macon	77 50 58.04	56.64	266 17 01.71	63,410.26	19,327.28		
Poplar	27 01 00.10	00 59.47	59 27 36.85	64,136.27	19,548.56	48 08 59.28	105 14 09.51
Spread Eagle	35 05 33.60	33.32	239 17 31.65	64,136.27	19,548.56		
Poplar	87 49 04.53	03.86	331 38 32.76	43,920.17	13,386.75		
Red Water	57 05 24.02	22.82	94 36 58.18	76,340.79	23,268.46	48 02 37.76	105 09 02.55
Poplar	49 56 42.61	43.78	331 38 32.76	43,920.17	13,386.75		
Redwater	61 28 15 01	15.27	213 10 36.57	36,111.38	11,006.65		
Deer Tail	68 34 59.99	35 00.95	101 49 14.23	41,449.15	12,633.59	48 07 35.92	105 04 11.31
Redwater	46 20 56.61	54.86	213 10 36.57	36,111.38	11,006.65		
Deer Tail	86 14 47.68	46.60	306 59 26.58	35,493.07	10,818.19		
Mortar Stone	47 24 21.35	18.54	79 40 18.54	48,948.60	14,919.40	48 04 04.97	104 57 13.97
Deer Tail	52 43 47.77	48.04	306 59 26.58	35,493.07	10,818.19		
Mortar Stone	95 21 34.13	35.16	222 26 12.49	53,434.73	16,286.76		
Box Elder	31 54 37.00	36.80	74 27 25.31	66,853.12	20,376.65	48 10 33.79	104 48 22.05
Mortar Stone	33 46 08.88	10.71	222 26 12.49	53,434.73	16,286.76		
Box Elder	71 42 14.19	14.05	330 50 34.34	30,819.08	9,393.57		
Devils Elbow	74 31 34.26	35.24	76 21 43.70	52,641.48	16,044.98	48 06 08.14	104 44 40.85
Box Elder	56 19 34.11	34.99	330 50 34.34	30,819.08	9,393.57		
Devils Elbow	91 52 41.08	41.65	242 46 00.84	48,678.21	14,836.98		
Big Muddy	31 47 42.29	43.36	94 41 39.55	58,461.31	17,818.84	48 09 47.47	104 34 02.50
Devils Elbow	37 12 10.16	11.42	242 46 00.84	48,678.21	14,836.98		
Big Muddy	79 24 16.05	16.82	343 29 39.25	32,919.37	10,033.73		
Boulder	63 23 30.75	31.75	100 07 49.88	53,516.00	16,311.53	48 04 35.98	104 31 44.79
Big Muddy	47 49 31.35	29.62	343 29 39.25	32,919.37	10,033.73		
Boulder	87 36 16.64	14.45	251 07 36.31	34,762.96	10,595.65		
Big Horn	44 34 16.25	15.92	115 47 52.87	46,866.46	14,284.77	48 06 26.66	104 23 40.17
Boulder	34 59 37.53	36.92	251 07 36.31	34,762.96	10,595.65		
Big Horn	107 15 34.12	35.75	323 58 01.12	32,566.26	9,926.11		
St. Ange	37 44 46.13	47.33	106 16 43.37	54,229.39	16,528.97	48 02 06.68	104 18 58.33
Big Horn	52 36 29.40	28.02	323 58 01.12	32,566.26	9,926.11		
St. Ange	75 15 43.98	43.15	219 17 14.02	32,776.20	9,990.09		
Lanark	52 07 49.99	48.83	91 28 50.30	39,896.73	12,160.41	48 06 16.91	104 13 52.58
St. Ange	71 33 44.65	46.70	219 17 14.02	32,776.20	9,990.09		
Lanark	61 40 48.91	49.54	337 40 11.84	42,685.01	13,010.27		
Cut Off	46 45 22.18	23.76	110 57 45.29	39,609.31	12,072.81	47 59 47.20	104 09 54.16
Lanark	35 47 42.11	42.47	337 40 11.84	42,685.01	13,010.27		
Cut Off	88 20 55.00	56.10	246 04 05.35	30,165.67	9,194.41		
Montana	55 51 22.38	21.44	122 00 28.25	51,553.64	15,713.41	48 01 47.75	104 03 08.55
Cut Off	42 20 49.60	49.85	246 04 05.35	30,165.67	9,194.41		
Montana	51 27 22.79	22.48	14 41 44.30	20,365.11	6,207.23		
Ferry	86 11 47.08	47.67	108 29 00.17	23,645.63	7,207.12	47 58 33.35	104 04 24.47

TABLE IV.—*Tabulated results of secondary triangulation from Fort Buford, N. Dak., to Bismarck, N. Dak.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first, in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	Feet.	Metres.	° ′ ″	° ′ ″
Montana	91 59 51.84	50.06	14 41 44.30	20,365.11	6,207.23		
Ferry	45 12 39.76	39.05	239 53 26.93	29,959.68	9,131.63		
Buford	42 47 32.08	30.90	102 45 39.69	21,275.43	6,484.69	48 01 01.49	103 58 03.31
Ferry	32 58 33.30	34.79	251 47 01.74	20,423.89	6,225.15		
West Base	117 13 30.88	32.56	314 36 59.78	22,369.91	6,818.29		
Glass Bluff	29 47 50.22	52.65	104 52 00.85	36,545.72	11,139.03	47 57 01.14	103 55 45.40
West Base	45 54 30.35	31.35	262 58 43.04	11,400.35	3,474.79	47 59 36.26	103 59 39.28
East Base	63 33 13.10	13.92	146 34 00.56	8,684.32	2,646.90	47 59 49.98	103 56 52.94
Buford	70 32 13.06	14.72	37 05 23.01	10,825.94	3,299.72		
Buford	93 06 15.82	17.62	338 54 57.52	26,100.31	7,955.30		
Glass Bluff	34 25 49.45	49.33	193 22 29.34	32,865.95	10,017.45		
Trenton	52 27 50.95	53.05	65 51 45.51	18,609.86	5,672.24	48 02 16.67	103 53 53.54
Glass Bluff	47 46 31.57	30.48	193 22 29.34	32,865.95	10,017.45		
Trenton	76 45 14.07	13.59	296 38 38.78	29,541.59	9,004.19		
Reservation	55 28 17.10	15.93	61 15 11.35	38,832.19	11,835.94	48 00 05.75	103 47 25.34
Trenton	58 34 10.07	07.78	296 38 38.78	29,541.59	9,004.19		
Reservation	78 53 25.53	24.47	195 36 51.91	37,281.74	11,363.37		
Jones Cut	42 32 27.76	27.75	58 11 09.59	42,874.11	13,067.91	48 06 00.05	103 44 57.51
Reservation	35 39 34.06	34.45	195 36 51.91	37,281.74	11,363.37		
Jones Cut	98 20 16.10	16.58	277 18 25.17	30,212.49	9,208.69		
Scott	46 00 08.68	08.97	51 23 44.47	51,277.74	15,629.32	48 05 21.90	103 37 36.16
Jones Cut	33 25 08.90	08.59	277 18 25.17	30,212.49	9,208.69		
Scott	107 57 10.41	10.63	205 21 04.25	26,655.15	8,124.42		
Williston	38 37 39.69	40.79	64 00 50.34	46,040.73	14,033.09	48 09 19.57	103 34 47.87
Scott	92 00 55.90	55.45	205 21 04.25	26,655.15	8,124.42		
Williston	42 29 00.11	28 58.37	342 54 10.90	37,347.17	11,383.31		
Ehorst	45 30 05.77	06.18	117 26 05.04	25,238.77	7,692.71	48 03 27.28	103 32 06.26
Ehorst	64 58 13.79	13.95	117 26 05.04	25,238.77	7,692.71		
Scott	34 11 36.32	36.85	331 33 36.51	23,164.26	7,060.40		
Geries	80 50 08.20	09.20	232 25 46.43	14,367.26	4,379.10	48 02 00.86	103 34 53.87
Geries	74 58 52.14	53.00	232 25 46.43	14,367.26	4,379.10		
Ehorst	79 06 02.02	02.85	333 21 48.18	31,748.07	9,676.72		
Lagoon	25 55 04.11	01.15	127 29 19.52	32,277.94	9,838.23	47 58 47.17	103 28 37.08
Ehorst	63 29 27.44	27.66	333 21 48.18	31,748.07	9,676.72		
Lagoon	37 37 55.30	51.42	191 02 18.14	28,953.95	8,825.09		
Bad Lands	78 52 38.74	37.92	89 55 56.75	19,755.90	6,021.57	48 03 27.61	103 27 15.48
Lagoon	67 10 33.63	33.65	191 02 18.14	28,953.95	8,825.09		
Bad Lands	55 01 04.58	05.15	316 02 13.59	31,535.54	9,611.95		
Plum	57 48 21.56	21.20	78 17 51.64	28,033.08	8,544.41	47 59 43.48	103 21 53.65
Band Lands	59 44 54.59	54.90	316 02 13.50	31,535.54	9,611.95		
Plum	49 26 07.08	07.54	185 32 20.43	28,842.69	8,791.17		
Harris	70 48 56.88	57.56	76 21 48.53	25,365.30	7,731.27	48 04 26.78	103 21 12.67
Plum	45 50 50.63	50.87	185 32 20.43	28,842.69	8,791.17		
Harris	97 04 20.00	19.64	268 28 31.20	34,322.56	10,461.42		
Fire Hill	37 04 49.24	49.49	51 29 57.55	47,473.18	14,469.69	48 04 35.48	103 12 47.48
Harris	41 40 20.32	18.62	268 28 31.20	34,322.56	10,461.42		
Fire Hill	90 18 49.04	48.35	178 53 35.46	30,699.82	9,357.22		
Nesson	48 00 54.90	53.03	46 54 22.06	46,174.18	14,073.76	48 09 38.38	103 12 56.24
Fire Hill	70 52 43.41	43.86	178 53 35.46	30,699.82	9,357.22		
Nesson	63 24 57.84	58.11	295 28 30.76	40,525.19	12,351.96		
Tobacco	45 42 17.40	18.03	69 52 54.16	38,357.11	11,691.14	48 06 46.02	103 03 57.17
Nesson	30 04 24.93	24.54	295 28 30.76	30,525.19	12,351.96		
Tobacco	114 38 23.82	23.58	230 13 35.87	35,154.31	10,714.94		
Grinnell	35 17 12.42	11.88	85 35 44.72	63,765.44	19,435.53	48 10 27.76	102 57 18.59
Tobacco	49 54 08.85	07.85	230 13 35.87	35,154.31	10,714.94		
Grinnell	81 55 00.87	00.62	328 23 31.46	36,083.17	10,998.05		
Lone Butte	48 10 52.40	51.54	100 16 07.50	46,702.23	14,234.71	48 05 24.41	102 52 40.07
Grinnell	48 47 30.26	31.29	328 23 31.46	36,083.17	10,998.05		
Lone Butte	26 34 47.89	47.99	175 01 47.11	28,055.47	8,551.23		
Strawberry	104 37 39.69	40.72	99 39 01.14	16,686.17	5,085.90	48 10 00.23	102 53 15.92
Lone Butte	78 40 32.92	31.93	175 01 47.11	28,055.47	8,551.23		
Strawberry	69 59 04.08	02.34	285 02 18.03	52,889.93	16,120.70		
White Earth	31 20 26.06	25.73	73 51 13.05	50,681.96	15,447.72	48 07 44.12	102 40 43.08
Lone Butte	107 14 34.00	34.03	175 01 47.11	28,055.47	8,551.23		
Strawberry	39 20 07.35	06.67	315 32 13.75	48,840.42	14,886.48		
Elk Horn	33 16 19.01	19.30	102 22 09.37	32,518.04	9,911.41	48 04 15.94	102 44 52.26
Elk Horn	92 08 47.76	45.63	218 41 57.16	27,040.84	8,241.97		
White Earth	33 03 33.04	31.56	5 41 31.03	33,070.58	10,079.82		
Crow Flies High	54 47 43.02	42.81	130 53 12.31	18,052.63	5,502.39	48 02 19.88	102 41 31.83
White Earth	44 16 25.02	25.69	5 41 31.03	33,070.58	10,079.82		
Crow Flies High	76 41 34.00	32.64	262 22 27.82	26,923.45	8,206.19		
Stony Hill	59 02 01.55	01.67	141 29 21.57	37,531.98	11,439.64	48 02 54.45	102 34 58.63

TABLE IV.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Crow Flies High	40 21 46.54	46.18	262 22 27.82	26,923.45	8,206.19		
Stony Hill	101 46 05.50	05.12	340 41 14.71	28,404.42	8,657.59		
Knife River	37 52 08.96	08.70	122 50 48.49	42,937.44	13,087.21	47 58 29.89	102 32 40.59
Crow Flies High	58 16 52.55	52.12	302 44 14.05	42,937.44	13,087.21		
Knife River	78 25 17.71	18.68	44 25 29.64	53,259.13	16,233.24		
Oak Ridge	43 17 48.54	49.20	181 00 54.50	61,337.04	18,695.36	47 52 14.17	102 41 47.32
Knife River	52 09 52.91	51.55	44 25 29.64	53,259.13	16,233.24		
Oak Ridge	61 13 38.26	40.19	285 32 24.05	45,829.39	13,968.67		
Second Ridge	66 36 29.61	28.26	172 16 52.44	50,864.39	15,503.33	47 50 12.49	102 31 00.20
Knife River	43 55 11.87	11.01	352 15 37.95	50,864.39	15,503.33		
Second Ridge	72 14 15.88	15.39	100 02 36.92	39,307.53	11,980.82		
Saddle Mountain	63 50 36.20	33.60	216 05 02.48	53,966.56	16,448.86	47 51 19.75	102 40 27.67
Saddle Mountain	40 58 09.81	08.35	279 55 36.25	39,307.53	11,980.82		
Second Ridge	80 06 31.82	32.26	19 56 04.57	30,091.10	9,171.68		
Indian Creek	58 55 19.54	19.39	140 58 53.97	45,212.86	13,780.76	47 45 33.30	102 33 30.34
Second Ridge	32 21 14.24	16.00	19 56 04.57	30,091.10	9,171.68		
Indian Creek	85 58 45.96	46.17	285 52 59.57	18,295.24	5,576.34		
Maneury	61 39 56.14	57.83	167 36 08.00	34,102.51	10,394.35	47 44 32.80	102 29 12.89
Second Ridge	33 12 58.16	57.32	347 34 48.52	34,102.51	10,394.35		
Maneury	116 37 38.60	38.12	284 13 46.12	37,186.28	11,334.27		
Independence	30 09 24.87	24.55	134 29 40.90	60,683.82	18,496.26	47 43 12.26	102 20 25.79
Second Ridge	23 09 02.32	08 59.93	314 21 51.12	60,683.82	18,496.26		
Independence	98 53 46.32	45.76	233 23 26.78	28,145.91	8,578.80		
Slide	57 57 16.65	14.31	111 24 45.98	70,731.79	21,558.85	47 45 58.77	102 14 55.11
Independence	84 14 14.95	15.36	233 23 26.78	28,145.91	8,578.80		
Slide	59 58 42.69	42.28	353 28 49.24	47,891.57	14,597.22		
Mission	35 47 03.07	02.36	137 42 45.40	41,676.89	12,703.00	47 38 09.18	102 13 35.72
Independence	29 47 17.82	18.43	317 37 42.23	41,676.89	12,703.00		
Mission	61 14 47.91	47.23	76 27 58.12	20,708.32	6,311.84		
Little Missouri	88 57 54.54	54.35	167 26 26.61	36,543.96	11,138.50	47 37 21.25	102 18 29.59
Mission	93 01 46.54	47.89	76 27 58.12	20,708.32	6,311.84		
Little Missouri	52 01 05.60	07.57	308 25 28.60	36,097.24	11,002.34		
Down	34 57 03.20	04.54	163 27 37.63	28,492.13	8,684.33	47 33 39.64	102 11 37.30
Mission	53 27 28.83	28.41	343 26 10.19	28,492.13	8,684.33		
Down	93 43 04.44	02.91	257 10 40.63	42,229.14	12,871.32		
Scoria	32 49 32.79	28.68	110 07 32.69	52,451.16	15,986.97	47 35 11.70	102 01 36.71
Down	42 32 14.17	15.22	257 10 40.63	42,229.14	12,871.32		
Scoria	66 58 32.68	33.42	10 19 30.43	30,289.62	9,232.19		
Cairn	70 29 10.18	11.36	119 49 20.74	41,233.53	12,567.86	47 30 17.60	102 02 55.77
Scoria	89 45 55.27	54.12	10 19 30.43	30,289.62	9,232.19		
Cairn	58 59 11.72	11.83	249 17 43.93	58,389.29	17,796.89		
Berthold	31 14 54.14	54.05	100 42 25.53	50,042.79	15,252.90	47 33 40.56	101 49 39.49
Cairn	23 54 35.31	35.73	249 17 43.93	58,389.29	17,796.89		
Berthold	95 25 03.20	02.03	334 02 29.28	27,143.91	8,273.39		
Guide Meridian	60 40 23.93	22.24	93 24 14.48	66,673.57	20,321.93	47 29 39.66	101 46 46.49
Berthold	58 45 45.82	47.07	334 02 29.28	27,143.91	8,273.39		
Guide Meridian	76 41 13.33	13.71	230 45 50.66	33,083.27	10,083.69		
Chippewa	44 32 58.49	59.22	95 23 25.34	37,652.75	11,476.48	47 33 06.02	101 40 32.98
Guide Meridian	29 35 37.86	37.98	230 45 50.66	33,083.27	10,083.69		
Chippewa	38 44 21.81	22.74	12 06 03.35	17,580.13	5,358.37		
Cook	111 39 58.07	59.27	80 25 24.47	22,286.82	6,789.91	47 30 16.36	101 41 26.65
Chippewa	76 47 26.68	26.70	12 06 03.35	17,580.13	5,358.37		
Cook	63 40 33.44	34.88	255 45 58.65	26,888.34	8,195.49		
Emanuel	39 31 58.08	58.41	115 22 37.11	24,755.09	7,545.28	47 31 21.44	101 35 06.96
Chippewa	41 51 51.82	49.89	295 18 36.62	24,855.09	7,545.28		
Emanuel	115 13 28.56	27.56	230 36 04.72	42,435.03	12,934.08		
Stevenson	22 54 45.47	42.55	73 36 40.33	57,523.22	17,532.92	47 35 46.98	101 27 08.57
Emanuel	67 45 01.77	04.54	230 36 04.72	42,435.03	12,934.08		
Stevenson	41 34 04.00	05.75	9 07 51.90	41,619.34	12,685.46		
Winslow	70 40 48.87	49.70	118 25 51.27	29,836.27	9,094.01	47 29 01.42	101 28 44.72
Stevenson	53 59 06.73	09.17	9 07 51.90	41,619.34	12,685.46		
Winslow	46 30 02.96	03.06	235 36 44.03	34,236.57	10,435.21		
Robinson	79 30 51.44	47.77	135 12 35.45	30,702.86	9,358.15	47 32 12.06	101 21 53.01
Stevenson	43 00 49.93	50.63	9 07 51.90	41,619.34	12,685.46		
Winslow	71 32 14.88	16.50	260 38 57.57	31,213.88	9,513.90		
Coal Harbor	65 26 49.95	52.86	146 11 21.10	43,401.51	13,228.66	47 29 51.23	101 21 16.24
Coal Harbor	48 57 07.25	05.06	80 44 28.15	31,313.88	9,513.90		
Winslow	72 04 18.40	14.94	332 43 12.50	27,469.00	8,372.47		
Hancock	58 58 41.65	40.01	211 44 07.48	34,654.83	10,562.70	47 25 00.43	101 25 41.67
Hancock	09 56 30.52	30.91	211 44 07.48	34,654.83	10,562.70		
Coal Harbor	43 37 10.53	10.13	348 10 12.77	57,469.16	17,516.44		
Sundguist	36 26 19.32	18.96	131 45 59.66	40,250.25	12,268.16	47 20 36.06	101 18 25.19
Hancock	52 26 58.10	58.42	311 40 38.49	40,250.25	12,268.16		
Sundguist	62 26 15.73	16.05	69 19 43.61	35,177.81	10,722.10		
Hoffman	65 06 45.56	45.53	184 07 06.74	39,334.98	11,989.19	47 18 33.22	101 26 22.75

TABLE IV.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Sundguist	34 18 09.72	08.91	69 19 43.61	35,177.81	10,722.10		
Hoffman	61 35 00.84	34 58.88	310 48 51.15	19,929.92	6,074.58		
Stanton	84 06 53.12	52.21	214 58 24.37	31,103.09	9,480.14	47 16 24.60	101 22 44.04
Stanton	25 43 34.52	34.64	214 58 24.37	31,103.09	9,480.14		
Sunguist	70 00 15.90	15 23	325 01 19.32	13,568.81	4,135.74		
Swenshern	84 16 10.90	10.14	60 46 32.14	29,374.82	8,953.36	47 18 46.81	101 16 32.32
Swenshern	115 16 22.40	22.17	60 46 32.14	29,374.82	8,953.36		
Stanton	37 58 32.64	31.62	278 40 30.63	59,012.92	17,986.97		
Mandan Lake	26 45 07.18	06.21	125 35 57.93	40,155.54	12,239.30	47 14 55.88	101 08 38.54
Swenshern	32 07 48.75	49.67	305 30 09.88	40,155.54	12,239.30		
Mandan Lake	117 09 36.32	36.96	242 45 35.01	41,819.74	12,746.54		
Washburn	30 42 33.03	33.36	93 34 44.72	69,960.79	21,323.85	47 18 04.45	100 59 39.14
Mandan Lake	53 48 07.21	07.53	242 45 35.01	41,819.74	12,746.54		
Washburn	39 57 34.10	34.42	22 54 36.76	33,820.64	10,308.44		
Ranch	86 14 16.97	18.05	116 37 58.67	26,916.58	8,204.10	47 12 56.94	101 02 49.83
Washburn	52 08 46.60	47.12	22 54 36.76	33,820.64	10,308.44		
Ranch	95 01 54.03	55.31	297 54 12.16	49,267.23	15,016.51		
Iverson	32 49 17.05	17.57	150 51 11.86	62,156.41	18,945.10	47 09 08.89	100 52 19.96
Ranch	37 27 41.47	39.58	297 54 12.16	49,267.23	15,016.51		
Iverson	94 58 44.92	43.26	23 03 10.76	40,604.13	12,376.03		
Square Butte	47 33 37.12	37.16	155 26 45.43	66,506.94	20,271.13	47 03 00.07	100 56 09.54
Iverson	36 25 06.70	06.70	23 03 10.76	40,604.13	12,376.03		
Square Butte	92 54 38.58	40.12	295 55 02.82	31,163.91	9,498.69		
Wogan	50 40 11.77	13.18	166 40 12.03	52,425.47	15,979.14	47 00 45.43	100 49 25.10
Square Butte	73 52 47.31	47.58	295 55 02.82	31,163.91	9,498.69		
Wogan	47 14 16.35	16.74	68 45 41.94	34,970.74	10,658.99		
Harmon	58 52 55.79	55.68	189 47 02.55	26,725.64	8,145.90	46 58 40.13	100 57 15.11
Wogan	40 09 00.83	08 58.80	68 45 41.94	34,970.74	10,658.99		
Harmon	46 16 42.74	43.99	294 56 42.27	22,592.44	6,886.11		
Sperry	93 34 18.13	17.20	208 34 35.31	25,322.97	7,718.37	46 57 05.97	100 52 12.87
Harmon	53 53 13.47	11.50	294 56 42.27	22,592.44	6,886.11		
Sperry	97 26 04.47	03.83	17 34 14.17	38,031.32	11,591.84		
Mandan	28 40 45.26	44.58	168 51 28.99	46,681.36	14,228.35	46 51 08.07	100 55 05.04
Sperry	43 21 54.38	54.69	17 34 14.17	38,031.32	11,591.84		
Mandan	72 39 21.84	21.09	270 11 34.75	29,059.63	8,857.29		
Marysville	63 58 45.98	44.22	154 15 24.04	40,397.02	12,312.90	46 51 06.89	100 48 06.99

TABLE V.—*Tabulated results of secondary triangulation from Bismarck to Pierre.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first, in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Mandan	60 28 43.41	44.13	270 11 34.75	29,059.63	8,857.29		
Marysville	67 55 58.13	56 00.50	22 20 39.16	32,271.91	9,836.39		
Lincoln	51 35 15.47	15.37	150 43 15.24	34,370.05	10,475.89	46 46 12.23	100 51 03.22
Marysville	69 20 47.61	45.60	22 20 39.16	32,271.91	9,836.39		
Lincoln	31 12 44.84	42.58	233 31 13.30	30,717.61	9,362.64		
Bismarck	79 26 36.15	31.82	133 02 03.99	17,011.42	5,185.03	46 49 12.34	100 45 08.11
Lincoln	49 10 19.15	20.43	233 31 13.30	30,717.61	9,362.64		
Bismarck	34 02 32.31	33.61	19 32 44.34	23,407.25	7,134.46		
South Base	96 47 03.54	05.96	102 44 30.51	17,317.26	5,278.25	46 45 34.60	100 47 00.60
Lincoln	58 23 38.83	40.72	282 41 33.76	17,317.26	5,278.25		
South Base	59 15 02.51	03.94	161 59 34.47	16,649.55	5,074.74		
North Base	62 21 15.47	15.34	44 19 55.93	16,800.33	5,120.85	46 48 10.89	100 48 14.58
Bismarck	32 42 51.55	49.43	53 35 17.98	30,717.61	9,362.64		
Lincoln	109 30 59.85	57.55	343 01 56.77	27,103.94	8,261.21		
Little Hart	37 46 15.47	18.02	200 49 32.43	47,270.15	14,407.81	46 41 56.32	100 49 09.74
Bismarck	52 18 43.62	45.86	20 52 28.48	47,270.15	14,407.81		
Little Hart	49 20 41.20	43.46	250 10 16.05	38,195.75	11,641.96		
Kayhall	78 20 26.20	30.68	148 37 02.29	36,616.92	11,160.74	46 44 03.89	100 40 33.96
Little Hart	71 19 40.89	41.14	250 10 16.05	38,195.75	11,641.96		
Kayhall	51 18 29.15	29.63	18 58 01.77	42,969.88	13,097.10		
Riverside	57 21 49.28	49.23	141 33 46.89	35,402.18	10,790.49	46 37 22.72	100 43 54.0[illegible]
Kayhall	61 46 44.08	44.37	18 58 01.77	42,969.88	13,097.10		
Riverside	77 41 33.40	32.56	276 37 08.97	58,264.91	17,758.98		
Glencoe	40 31 43.43	43.07	137 18 54.52	64,605.28	19,691.51	46 36 15.59	100 30 05.23
Riverside	64 59 49.83	50.13	276 37 08.97	58,264.91	17,758.98		
Glencoe	36 58 28.75	28.04	59 48 43.06	53,978.80	16,452.59		
Fort Rice	78 01 40.82	41.83	161 38 56.56	35,823.09	10,918.78	46 31 47.13	100 41 12.[illegible]
Glencoe	49 13 50.35	48.54	59 48 43.06	53,978.80	16,452.59		
Fort Rice	58 22 17.97	16.90	298 02 55.61	42,888.27	13,072.22		
McIntyre	72 23 56.86	54.56	190 33 22.56	48,218.51	14,696.87	46 28 27.70	100 32 11.[illegible]

TABLE V.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Fort Rice	47 42 01.02	01.70	298 02 55.61	42,888.27	13,072.22		
McIntyre	75 06 46.00	45.31	43 02 42.42	37,744.06	11,504.28		
Cannon Ball	57 11 11.60	12.99	165 47 02.99	49,317.58	15,031.86	46 23 55.25	100 38 19.27
McIntyre	48 12 53.80	53.60	43 02 42.42	37,744.06	11,504.28		
Cannon Ball	49 16 53.36	53.36	272 15 09.52	28,386.53	8,652.14		
Gayton	82 30 13.66	13.04	174 50 15.63	28,853.73	8,794.54	46 23 44.04	100 31 34.64
Cannon Ball	57 16 29.58	28.28	272 15 09.52	28,386.53	8,652.14		
Gayton	61 15 48.60	50.12	31 04 12.34	27,183.66	8,285.50		
Givens	61 27 40.84	41.60	149 34 06.02	28,333.11	8,635.85	46 19 54.15	100 34 54.54
Gayton	31 28 24.83	24.96	31 04 12.34	27,183.66	8,285.50		
Givens	108 29 47.83	46.50	319 31 34.23	22,066.22	6,725.72		
Beaver Creek	40 01 47.77	48.54	179 35 50.25	40,080.61	12,216.46	46 17 08.40	100 31 30.62
Givens	65 24 25.60	24.66	319 31 34.23	22,066.22	6,725.72		
Beaver Creek	64 05 02.32	01.83	75 28 59.80	25,999.46	7,924.56		
Van Solen	50 30 33.99	33.51	204 54 07.38	25,717.77	7,838.70	46 16 03.91	100 37 28.84
Beaver Creek	65 39 23.72	24.78	75 28 59.80	25,999.46	7,924.56		
Van Solen	64 13 36.98	36.99	319 38 17.97	30,870.02	9,409.10		
Little Beaver	50 06 57.54	58.23	189 48 41.49	30,511.80	9,299.91	46 12 11.61	100 32 44.64
Van Solen	49 11 35.30	34.81	319 38 17.97	30,870.02	9,409.10		
Little Beaver	87 34 06.21	05.29	52 07 37.82	34,108.87	10,396.29		
Battle Creek	43 14 19.48	19.90	188 48 42.00	45,022.42	13,722.71	46 08 44.72	100 39 07.00
Little Beaver	52 17 04.84	03.69	52 07 37.82	34,108.87	10,396.29		
Battle Creek	60 44 13.29	13.42	292 47 15.48	29,316.97	8,935.73		
Cathead	66 58 43.97	42.89	179 50 34.98	32,330.98	9,854.39	46 06 52.45	100 32 43.38
Battle Creek	53 08 04.54	03.48	292 47 15.48	29,316.97	8,935.73		
Cathead	36 03 55.08	54.97	76 47 57.02	23,457.15	7,149.67		
Fort Yates	90 48 02.87	01.55	165 56 01.93	17,260.77	5,261.03	46 05 59.44	100 38 07.42
Cathead	72 35 25.44	25.71	76 47 57.02	23,457.15	7,149.67		
Fort Yates	43 33 05.08	04.08	300 17 07.63	24,933.13	7,599.55		
Winona	63 51 30.85	30.21	104 12 17.78	18,003.65	5,487.46	46 03 55.20	100 33 02.12
Fort Yates	38 58 47.74	46.09	300 17 07.63	24,933.13	7,599.55		
Winona	105 14 14.56	13.83	15 06 33.65	26,822.97	8,175.57		
Fire Heart	35 47 01.04	00.08	159 18 22.26	41,142.00	12,539.97	45 59 39.55	100 34 41.14
Winona	43 43 23.51	23.82	15 06 33.65	26,822.97	8,175.57		
Fire Heart	50 57 59.66	58.99	246 03 21.41	18,601.73	5,669.75		
McRay	85 18 38.32	37.19	151 24 51.90	20,905.44	6,371.92	46 00 54.01	100 30 40.28
McRay	50 10 44.43	43.71	66 06 14.68	18,601.73	5,669.75		
Fire Heart	95 22 17.54	16.10	341 25 37.55	25,255.97	7,697.95		
Martin	34 27 00.91	00.19	195 53 59.58	32,739.00	9,978.76	45 55 43.20	100 32 47.35
McRay	55 41 48.69	48.10	15 55 30.94	32,739.00	9,978.76		
Martin	43 10 23.03	22.44	239 04 22.06	27,371.97	8,342.90		
Doerschlag	81 07 50.63	49.46	140 16 10.43	22,671.20	6,910.12	45 58 01.94	100 27 14.98
Martin	106 43 30.98	31.62	239 04 22.06	22,371.97	8,342.90		
Doerschlag	40 22 33.13	32.47	18 45 48.46	48,262.21	14,710.19		
St. Benedict	32 53 54.58	55.91	165 49 15.03	32,645.15	9,950.15	45 50 30.75	100 30 54.23
Doerschlag	50 53 16.75	17.20	18 45 48.46	48,262.21	14,710.09		
St. Benedict	38 46 25.83	24.62	237 29 35.67	37,448.16	11,414.09		
La Grace	90 20 18.80	18.18	147 55 14.43	30,224.42	9,212.32	45 53 49.18	100 23 27.76
St. Benedict	76 28 08.11	07.56	237 29 35.67	37,448.16	11,414.09		
La Grace	52 59 33.55	33.90	4 35 22.11	47,158.35	14,373.73		
Box Elder	50 32 19.49	18.54	134 02 25.28	38,733.90	11,805.98	45 46 05.12	100 24 20.98
La Grace	32 59 57.85	58.23	4 35 22.11	47,158.35	14,373.73		
Box Elder	84 52 38.32	37.48	269 27 21.51	29,055.73	8,856.11		
Kirkland	62 07 24.74	24.29	151 39 39.53	53,136.04	16,195.72	45 46 07.63	100 17 31.17
Box Elder	61 58 55.24	55.88	269 27 21.51	29,055.73	8,856.11		
Kirkland	64 57 38.00	38.82	24 34 36.23	32,093.79	9,782.09		
Blume	53 03 26.13	25.30	151 28 56.25	32,937.81	10,039.35	45 41 19.45	100 20 39.18
Kirkland	45 34 31.20	30.93	24 34 36.23	32,093.79	9,782.09		
Blume	67 56 21.71	21.33	272 28 43.02	24,996.21	7,618.77		
Campbell	66 29 08.02	07.74	159 02 02.47	32,437.73	9,886.93	45 41 08.63	100 14 47.46
Blume	88 46 43.45	45.28	272 28 43.02	24,996.21	7,618.77		
Campbell	52 03 29.39	31.55	40 29 23.05	39,572.35	12,061.54		
Roth	39 09 42.77	43.17	181 15 21.45	31,215.49	9,514.40	45 36 11.35	100 20 48.81
Blume	46 37 25.54	24.76	1 15 28.34	31,215.49	9,514.40		
Roth	69 03 09.03	06.66	112 12 14.73	25,174.96	7,673.26		
Ashley	64 19 31.88	28.58	227 48 51.73	32,346.02	9,858.98	45 37 45.15	100 26 16.76
Roth	81 00 21.41	18.90	112 12 14.73	25,174.96	7,673.26		
Ashley	37 02 33.23	32.69	329 10 53.08	28,174.25	8,587.43		
Aske	61 57 10.41	08.42	211 10 26.45	17,183.65	5,237.53	45 33 46.22	100 22 53.90
Ashley	57 30 06.63	07.59	329 10 53.08	28,174.25	8,587.43		
Aske	70 28 25.66	25.78	78 44 52.15	30,145.22	9,188.18		
Grand River	52 01 25.88	26.62	206 38 28.93	33,686.36	10,267.51	45 32 47.94	100 29 49.28
Aske	61 50 06.62	06.98	78 44 52.15	30,145.22	9,188.18		
Grand River	55 41 41.75	42.63	314 21 38.31	29,969.43	9,134.60		
Blue Blanket	62 28 09.79	10.39	196 53 23.30	28,081.26	8,559.09	45 29 20.96	100 24 48.56
Aske	49 09 49.17	48.83	16 54 45.11	28,081.26	8,559.09		
lue Blanket	83 25 28.18	28.01	280 18 51.37	28,857.17	8,795.59		
ox Island	47 24 43.63	43.16	147 48 18.62	37,890.61	11,548.95	45 28 29.75	100 18 10.20

TABLE V.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Blue Blanket	41 45 23.58	22.55	280 18 51.37	28,857.17	8,795.59		
Fox Island	74 51 12.86	13.24	25 32 22.11	21,494.60	6,551.49		
Curlew	63 23 25.39	24.21	142 07 25.28	31,154.74	9,495.88	45 25 18.25	100 20 20.10
Fox Island	61 58 04.78	05.72	25 32 22.11	21,494.60	6,551.49		
Curlew	79 23 57.48	56.49	284 54 46.08	30,389.69	9,262.69		
Bennett	38 37 57.88	57.79	143 37 36.96	33,840.88	10,314.61	45 24 00.83	100 13 28.60
Curlew	55 23 02.03	00.80	284 54 46 08	30,389.69	9,262.69		
Bennett	73 45 31.53	30.85	31 14 08.20	32,246.61	9,828.67		
Le Beau	50 51 28 53	28.35	160 19 53.28	37,619.32	11,466.26	45 19 28.54	100 17 22.61
Bennett	40 47 59.93	60.85	31 14 08.20	32,246.61	9,828.67		
Le Beau	46 41 13.17	12.50	257 52 34.24	21,091.04	6,428.49		
McKinley	92 30 46.97	46.65	170 26 46.18	23,485.70	7,158.38	45 20 12.18	100 12 33.97
Le Beau	72 58 04.52	05.37	257 52 34.24	21,091.04	6,428.49		
McKinley	70 54 37.44	37.27	7 01 22.17	34,208.73	10,426.73		
Scranton	36 07 17.95	17.36	150 53 23.22	33,810.38	10,305.31	45 14 36.96	100 13 32.42
Le Beau	39 01 28.28	29.12	330 50 39.66	33,810.38	10,305.31		
Scranton	86 20 03.67	02.52	64 33 20.64	26,104.01	7.956.43		
St. Stephen	54 38 29.09	28.36	189 50 58.50	41,372.62	12,610.26	45 12 46.10	100 19 01.65
Scranton	59 29 39.58	39.19	64 33 20.64	26,104.01	7,956.43		
St. Stephen	89 17 27.78	27.40	333.46 54.42	43,397.42	13,227.41		
Bunker Hill	31 12 53.59	53.41	185 02 57.43	50.365.83	15,351.36	45 06 21.61	100 14 34.37
St. Stephen	34 43 37.41	38.83	333 46 54.42	43,397.42	13,227.41		
Bunker Hill	97 13 06.84	08.62	56 36 55.20	33,239.39	10,131.27		
Charger	48 03 09.18	12.55	188 29 08.81	57,885.45	17,643.32	45 03 20.84	100 21 00.95
Bunker Hill	37 05 12.91	11.99	56 36 55.20	33,239.39	10,131.27		
Charger	96 50 44.19	43.31	333 23 04.85	27,832.71	8,483.33		
Forest City	46 04 04.44	04.70	199 29 12.32	45,826.32	13.967.74	44 59 15.11	100 18 07.48
Charger	77 06 52.82	51.67	333 23 04.85	27,832.71	8.483.33		
Forest City	61 48 57.83	57.86	91 36 09.62	41,298.19	12,587.57		
Travessy	41 04 11.22	10.47	230 25 13.04	37,341.98	11.381.73	44 59 26.12	100 27 41.83
Forest City	37 20 40.21	39.07	91 36 09.62	41,298.19	12,587.57		
Travessy	80 54 59.49	57.33	352 24 21.02	28.441.58	8,668.91		
Pascal	61 44 25.70	23.60	234 09 21.61	46,298.68	14,111.71	44 54 47.75	100 26 49.60
Forest City	39 45 48.41	48.24	54 15 30.46	46,298.68	14,111.71		
Pascal	83 40 21.92	23.02	317 49 44.76	35,486.75	10,816.26		
Artichoke	56 33 48.80	48.73	194 27 26.87	55,143.00	16,807.43	44 50 27.93	100 21 19.01
Artichoke	97 38 10.89	10.95	137 53 38.01	35,486.75	10,816.26		
Pascal	36 46 21.17	21.59	354 36 06.42	49,235.56	15,006.86		
Fairbank	45 35 27.81	27.46	220 12 19.24	29,738.18	9,064.12	44 46 43.75	100 25 45.40
Pascal	66 00 49.37	48.76	354 36 06.42	49,235.56	15,006.86		
Fairbank	47 10 48.39	47.06	127 26 04.52	48,938.96	14,916.46		
Plum Island	66 48 26.14	24.19	240 31 19.98	39,289.05	11,975.20	44 51 37.13	100 34 44.83
Fairbank	101 02 12.11	10.52	127 26 04.52	48,938.96	14,916.46		
Plum Island	30 00 24.35	23.55	337 29 08.00	63,832.60	19,456.00		
Sully	48 48 26.81	25.93	206 21 32.30	32,671.44	9,958.10	44 41 54.74	100 29 06.48
Plum Island	49 11 06.03	07.55	337 29 08.00	63,832.60	19,456.00		
Sully	69 13 14.14	13.67	88 19 52.37	54,923.29	16,740.47		
Fort Bennett	61 35 37.37	38.78	206 35 18.88	67,849.56	20,680.36	44 41 38.25	100 41 46.38
Fort Bennett	76 58 31.83	28.79	268 10 57.93	54,923.29	16,740.47		
Sully	55 15 35.71	34.95	33 04 17.15	72,271.78	22,028.24		
Fielder	47 45 55.22	56.26	165 11 58.31	60,957.28	18,579.61	44 31 56.36	100 38 10.84
Sully	32 04 33.04	35.11	33 04 17.15	72,271.78	22,028.24		
Fielder	78 26 22.41	20.98	291 24 16.06	40,979.06	12,490.30		
Ingham	69 29 05.08	03.91	180 59 29.12	75,600.37	23,042.78	44 29 28.34	100 29 24.58
Fielder	35 06 29.75	31.05	291 24 16.06	40,979.06	12,490.30		
Ingham	95 48 23.60	23.96	15 42 00.92	31,188.15	9,506.06		
Ferry	49 05 03.62	04.99	146 35 34.43	53,949.91	16,443.78	44 24 31.84	100 31 20.83
Ferry	52 34 28.80	28.74	195 40 39.52	31,188.15	9,506.06		
Ingham	36 26 48.30	48.50	339 15 12.39	24,771.62	7,550.32		
Brown Hill	90 58 43.38	42.76	68 17 54.27	18,530.83	5,648.15	44 25 39.58	100 27 23.68
Ingham	52 48 14.18	11.89	339 15 12.39	24,771.62	7,550.32		
Brown Hill	63 32 59.79	58.41	222 49 35.51	22,020.65	6,711.83		
Stony Hill	63 38 51.11	49.70	106 30 49.78	24,750.68	7,543.94	44 28 19.00	100 23 57.26
Brown Hill	47 58 42.34	42.76	222 49 35.51	22,020.65	6,711.83		
Stony Hill	73 01 26.49	27.61	329 50 32.41	19,085.55	5,817.22		
Snake Butte	58 59 48.13	49.63	90 52 15.25	24,571.50	7,489.33	44 25 36.03	100 21 45.15
Brown Hill	56 55 51.72	50.85	270 48 18.30	24,571.50	7,489.33		
Snake Butte	63 53 40.03	40.52	26 58 34.69	23,978.60	7,308.61		
Fort	59 10 30.01	28.63	147 46 21.28	25,694.67	7,831.66	44 22 04.98	100 24 14.87
Snake Butte	45 47 10.20	10.75	26 58 34.69	23,978.60	7,308.61		
Fort	47 34 38.82	37.94	254 31 27.91	17,216.22	5,247.46		
Pierre	86 38 11.61	11.31	161 12 18.99	17,731.23	5,404.43	44 22 50.28	100 20 26.44
Fort	54 24 50.18	49.70	254 31 27.91	17,216.22	5,247.46		
Pierre	71 28 45.75	46.67	3 05 20.96	17,282.78	5,267.74		
Bad River	54 06 24.43	23.63	128 58 48.35	20,151.12	6,142.01	44 19 30.86	100 20 39.25
Pierre	61 39 40.46	40.13	3 05 20.96	17,282.78	5,267.74		
Bad River	37 59 01.11	03.31	221 04 15.33	15,429.70	4,702.93		
Cemetery	80 21 17.58	16.56	121 27 09.43	10,789.12	3,288.49	44 21 54.71	100 18 19.73

TABLE VI.—*Tabulated results of secondary triangulation from Pierre to Running Water*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Bad River	31 56 10.63	11.33	221 04 15.33	15,429.70	4,702.93		
Cemetery	78 12 14.10	15.51	322 53 37.33	8,693.63	2,649.80		
East Base	69 51 31.88	33.16	73 02 54.61	16,087.69	4,903.48	44 20 46.24	100 17 07.56
Cemetery	94 56 12.64	15.35	322 53 37.33	8,693.63	2,649.80		
East Base	38 51 34.64	36.61	104 02 51.17	11,999.89	3,657.53		
West Base	46 12 08.49	08.04	237 48 51.15	7,557.04	2,303.36	44 21 14.97	100 19 47.76
Bad River	62 30 23.06	23.28	221 04 15.33	15,429.70	4,702.93		
Cemetery	46 19 22.60	23.88	354 46 20.20	14,461.12	4,407.71		
Plateau	71 10 13.56	12.83	103 36 20.03	11,790.49	3,593.71	44 19 32.50	100 18 01.60
Cemetery	62 22 53.78	52.82	354 46 20.20	14,461.12	4,407.71		
Plateau	73 57 56.39	56.33	248 44 29.22	18,562.23	5,657.72		
Barth	43 39 12.88	10.85	112 26 26.42	20,134.35	6,136.89	44 20 38.80	100 14 03.58
Plateau	42 57 50.70	50.84	248 44 29.22	18,562.23	5,657.72		
Barth	68 48 36.70	37.11	359 58 38.42	13,622.83	4,152.20		
Farm Island	68 13 30.29	32.05	111 45 06.40	18,636.94	5,680.49	44 18 24.37	100 14 03.51
Barth	84 09 16.52	17.99	359 58 38.42	13,622.83	4,152.20		
Farm Island	64 03 28.90	29.70	244 02 08.20	25,727.15	7,841.56		
Perry	31 47 12.56	12.31	95 53 02.85	23,255.76	7,088.29	44 20 15.48	100 08 45.29
Farm Island	39 16 13.38	13.03	244 02 08.20	25,727.15	7,841.56		
Perry	82 42 41.04	41.09	341 23 09.39	19,198.73	5,851.72		
Narselles	58 01 05.24	05.88	103 23 02.31	30,085.76	9,170.06	44 17 15.80	100 07 21.06
Perry	53 09 22.57	22.47	341 23 09.39	19,198.73	5,851.72		
Narselles	52 56 54.16	53.14	214 21 01.39	15,991.79	4,874.25		
Rousseau	73 53 44.53	44.39	108 16 12.48	15,948.15	4,860.95	44 19 26.16	100 05 16.95
Narselles	43 12 34.68	34.56	214 21 01.39	15,991.79	4,874.25		
Rousseau	93 35 41.45	42.50	300 46 45.56	15,996.05	4,875.55		
Jacques	43 11 42.92	42.94	77 37 14.58	23,317.12	7,106.99	44 18 05.28	100 02 08.00
Jacques	78 18 59.35	58.54	77 37 14.58	23,317.12	7,106.99		
Narselles	49 48 20.55	29.15	307 22 05.16	29,026.05	8,847.06		
Fort George	51 52 31.16	32.31	179 18 18.64	22,641.76	6,901.15	44 14 21.71	100 02 04.22
Jacques	74 01 54.74	53.53	359 18 16.01	22,641.76	6,901.15		
Fort George	70 23 54.88	56.66	249 42 15.36	37,422.12	11,406.16		
Chapelle Creek	35 34 07.32	09.81	105 22 01.84	36,668.63	11,176.50	44 16 29.61	99 54 01.86
Fort George	77 58 31.71	33.41	249 42 15.36	37,422.12	11,406.16		
Chapelle Creek	68 05 28.65	29.83	1 42 21.95	65,568.10	19,984.97		
Cedar River	33 55 57.69	56.76	147 46 06.37	62,197.49	18,957.62	44 05 42.40	99 54 28.06
Chapelle Creek	46 25 12.22	09.10	1 42 21.95	65,568.10	19,984.97		
Cedar River	48 07 00.93	01.32	229 49 04.82	47,646.82	14,522.62		
Reynolds	85 27 50.32	49.58	135 22 42.38	48,969.52	14,925.77	44 10 45.69	99 46 09.14
Cedar River	61 22 48.44	49.50	229 49 04.82	47,646.82	14,522.62		
Reynolds	78 57 11.56	12.56	330 57 39.82	65,524.80	19,971.78		
Burnt Ridge	39 39	57.94	111 22 44.51	73,261.95	22,330.04	44 01 19.73	99 38 53.90
Reynolds	42 45 13.76	15.78	330 57 39.82	65,524.80	19,971.78		
Burnt Ridge	47 51	22.35	198 54 05.21	44,484.35	13,558.70		
Neck	89 23 19.97	21.87	108 19 44.70	48,586.99	14,809.18	44 08 15.29	99 35 36.32
Neck	57 36 11.09	11.31	108 19 44.70	48,586.99	14,809.18		
Reynolds	44 07 02.13	02.35	244 05 21.42	41,898.35	12,770.50		
Big Bend	78 16 46.11	46.34	345 54 35.77	34,543.06	10,528.63	44 13 46.16	99 37 31.62
Neck	89 51 26.53	25.93	18 56 22.65	44,484.35	13,558.70		
Burnt Ridge	42 45 23.78	24.72	241 39 30.07	60,446.18	18,423.83		
Fort Thompson	47 23 10.92	09.35	109 11 06.48	41,036.36	12,507.77	44 06 02.46	99 26 44.92
Burnt Ridge	44 40 58.88	58.63	241 39 30.07	60,446.18	18,423.83		
Fort Thompson	49 49 38.98	40.60	11 58 16.24	42,636.68	12,995.54		
Badger Creek	85 29 19.42	20.77	106 27 31.23	46,331.10	14,121.59	43 59 10.55	99 28 45.86
Fort Thompson	68 31 49.89	48.91	11 58 16.24	42,636.68	12,995.54		
Badger Creek	58 02 30.54	30.77	249 59 23.08	49,405.81	15,058.75		
Wolf Creek	53 25 42.98	40.32	123 32 24.96	45,043.12	13,729.02	44 01 57.01	99 18 10.48
Badger Creek	42 56 35.54	33.05	249 59 23.08	49,405.81	15,058.75		
Wolf Creek	58 50 25.31	25.80	11 16 18.58	34,382.93	10,479.82		
Bluff	78 13 02.27	01.15	113 02 13.53	43,187.96	13,163.57	43 56 24.00	99 19 42.32
Bluff	68 42 49.91	48.48	113 02 13.53	43,187.96	13,163.57		
Badger Creek	33 58 29.89	28.58	326 54 24.89	41,248.82	12,572.52		
Fort Lookout	77 18 44.48	42.94	224 16 41.28	24,738.65	7,540.27	43 53 29.15	99 23 38.34
Fort Lookout	72 28 03.36	03.81	224 16 41.28	24,738.65	7,540.27		
Bluff	62 02 34.63	33.73	342 16 51.19	33,079.11	10,082.42		
Prichard	45 29 24.01	22.46	116 49 03.92	30,641.99	9,339.59	43 51 12.80	99 17 24.94
Prichard	97 11 42.18	42.84	116 49 03.92	30,641.99	9,339.59		
Fort Lookout	35 55 31.76	32.92	332 40 18.13	41,649.83	12,694.75		
Chamberlain	46 52 44.80	44.24	199 36 02.96	24,631.47	7,507.60	43 47 23.66	99 19 17.70
Fort Lookout	48 42 00.36	00.14	332 40 18.13	41,649.83	12,694.75		
Chamberlain	65 37 51.16	51.68	87 05 26.87	34,340.02	10,466.74		
Brulé	65 40 08.03	08.18	201 19 55.13	41,637.35	12,690.95	43 47 06.18	99 27 05.15

TABLE VI.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Chamberlain	85 26 55.68	53.44	87 05 26.87	34,340.02	10,466.74		
Brulé	59 26 37.25	35.82	326 26 39.37	59,520.25	18,141.60		
Willrodt	35 06 32.13	30.74	181 38 19.43	51,416.62	15,671.64	**43 38 56.08**	**99 19 37.74**
Brulé	47 22 10.18	09.01	326 26 39.37	59,520.25	18,141.60		
Willrodt	64 40 38.54	39.12	81 51 09.24	47,245.52	14,400.30		
Indian	67 57 11.76	11.87	193 46 38.40	58,045.63	17,692.15	**43 37 49.46**	**99 30 13.57**
Willrodt	54 51 53.30	53.47	81 51 09.24	47,245.52	14,400.30		
Indian	64 14 19.36	20.10	325 58 10.73	44,220.51	13,478.29		
Rosebud	60 53 46.26	46.43	206 55 48.84	48,698.67	14,843.22	**43 31 47.39**	**99 24 37.60**
Rosebud	70 55 36.99	37.26	206 55 48.84	48,698.67	14,843.22		
Willrodt	47 40 01.20	00.56	339 19 14.92	52,418.52	15,977.02		
Bijou	61 24 22.62	22.18	97 57 45.74	41,000.60	12,496.87	**43 30 51.66**	**99 15 26.56**
Rosebud	41 00 55.82	54.75	277 51 28.24	41,000.60	12,496.87		
Bijou	50 14 46.58	46.40	47 42 59.26	26,913.55	8,203.17		
Durex	88 44 19.24	18.85	138 55 34.57	31,528.89	9,609.92	**43 27 52.74**	**99 19 56.52**
Bijou	62 46 06.97	07.87	47 42 59.26	26,913.55	8,203.17		
Durex	80 37 14.04	14.62	308 17 08.20	40,127.15	12,230.64		
Brickkiln	36 36 35.33	37.51	164 58 39.02	44,525.41	13,571.22	**43 23 46.97**	**99 12 49.96**
Bijou	39 03 46.70	45.48	344 56 51.32	44,525.41	13,571.22		
Brickkiln	66 14 01.20	00.36	231 12 39.48	29,089.02	8,866.25		
Heaton	74 42 14.82	14.16	125 58 24.95	42,245.97	12,876.45	**43 26 46.83**	**99 07 42.65**
Brickkiln	83 38 03.50	02.87	231 12 39.48	29,089.02	8,866.25		
Heaton	45 48 02.45	01.85	5 28 08.78	37,430.67	11,408.76		
Cologne	50 33 56.55	55.28	134 53 40.28	27,001.26	8,229.91	**43 20 38.83**	**99 08 30.92**
Heaton	58 30 01.01	01.26	5 28 08.78	37,430.67	11,408.76		
Cologne	56 21 31.15	31.29	241 49 06.99	35.174.07	10,720.96		
Boland	65 08 27.91	27.45	127 02 22.80	34,344.01	10,467.96	**43 23 22.68**	**99 01 31.08**
Cologne	71 07 33.13	34.74	241 49 06.99	35,174.07	10,720.96		
Boland	57 10 40.20	39.32	4 43 15.85	42,412.83	12,927.31		
Hamilton	51 41 44.88	45.94	133 00 57.43	37,667.15	11,480.84	**43 16 25.20**	**99 02 18.26**
Boland	57 18 54.16	56.06	4 43 15.85	42,412.83	12,927.31		
Hamilton	73 05 07.08	07.18	257 47 50.81	46,875.60	14,287.55		
Kyle	49 35 54.99	56.76	127 30 52.46	53,284.98	16,241.11	**43 18 02.59**	**98 51 58.75**
Hamilton	46 16 13.80	12.87	257 47 50.81	46,875.60	14.287.55		
Kyle	45 18 08.84	10.10	32 36 45.36	33,885.34	10,328.16		
Mule Head	88 25 36.59	37.03	124 08 19.23	33,333.32	10,159.90	**43 13 20.61**	**98 56 05.37**
Mule Head	67 31 11.64	10.60	212 33 56.35	33,885.34	10,328.16		
Kyle	57 02 46.58	46.14	335 33 59.13	38,022.27	11,589.08		
Wheeler	55 26 05.23	03.26	100 10 21.26	34,528.65	10,524.24	**43 12 20.63**	**98 48 26.42**
Wheeler	88 25 07.67	08.42	100 10 21.26	34.528.65	10,524.24		
Mule Head	46 43 48.02	47.31	326 48 54.44	48,939.56	14,916.64		
Whetstone	44 51 04.24	04.27	191 44 05.81	35,647.79	10,865.35	**43 06 35.91**	**98 50 04.30**
Whetstone	65 00 48.88	46.71	191 44 05.81	35.647.79	10,865.35		
Wheeler	77 12 33.15	31.72	294 32 40.90	52,743.93	16,076.20		
Leonard	37 46 39.81	41.57	76 53 21.91	56,746.25	17,296.10	**43 08 43.72**	**98 37 39.33**
Leonard	50 22 57.74	57.87	76 53 21.91	56,746.25	17,296.10		
Whetstone	42 36 13.00	12.97	299 21 05.76	43,772.29	13,341.67		
Chicot	87 00 50.25	49.16	206 27 45.96	38,464.91	11,724.00	**43 03 03.67**	**98 41 30.51**
Chicot	58 15 17.57	15.55	206 27 45.96	38,464.91	11,724.00		
Leonard	77 57 20.19	18.64	308 33 05.12	47,267.53	14,407.01		
White Swan	43 47 24.97	25.81	84 51 19.38	54,359.56	16,568.64	**43 03 52.46**	**98 29 21.43**
White Swan	54 01 06.46	05.54	84 51 19.38	54,359.56	16,568.64		
Chicot	55 15 03.42	03.89	319 58 05.70	46,598.51	14,203.09		
Harrison	70 43 51.82	50.57	210 46 31.27	47,315.51	14,421.63	**42 57 11.06**	**98 34 47.52**
White Swan	49 48 26.45	25.98	30 50 13.68	47,315.51	14,421.63		
Harrison	83 50 54.76	54.76	294 37 26.22	49,956.08	15,226.48		
Bruce	46 20 39.92	39.26	161 05 01.08	65,021.49	19,818.37	**42 53 45.01**	**98 24 37.50**
Bruce	94 15 26.58	27.67	161 05 01.08	65,021.49	19,818.37		
White Swan	36 09 59.28	59.07	304 51 48.20	85,176.65	25,961.60		
Conger	49 34 32.19	33.26	75 27 55.22	50,404.43	15,363.13	**42 55 50.48**	**98 13 42.09**
Conger	81 07 26.63	29.12	75 27 55.22	50,404.43	15,363.13		
Bruce	52 29 40.15	42.80	307 50 11.98	68,792.32	20,967.70		
Ponca	46 22 47.83	48.08	174 21 15.53	55,234.46	16,835.31	**42 46 47.56**	**98 12 29.0**
Conger	40 42 50.51	46.86	354 20 25.86	55,234.46	16,835.31		
Ponca	32 55 35.68	36.00	207 16 51.62	37,548.03	11,444.54		
Chouteau	106 21 39.49	37.14	133 41 05.93	31,290.50	9,537.26	**42 52 17.12**	**98 08 37.**
Ponca	83 13 52.82	51.66	207 16 51.62	37,548.03	11,444.54		
Chouteau	40 08 54.64	53.42	347 10 35.20	44,651.70	13,609.71		
Ward	56 37 14.84	14.92	110 34 50.45	28,902.01	8,836.69	**42 45 07.05**	**98 06 25.**
Chouteau	35 13 10.91	10.32	347 10 35.20	44,651.70	13,609.71		
Ward	50 19 05.26	04.44	217 31 09.96	25,829.34	7,872.71		
Arneson	94 27 46.66	45.24	132 01 18.58	34,468.40	10,505.87	**42 48 29.35**	**98 02 54.**
Ward	62 13 02.81	03.20	217 31 09.96	25,829.34	7,872.71		
Arneson	77 34 16.48	16.85	319 59 16.34	35,395.97	10,788.59		
Niobrara	40 12 39.79	39.95	99 50 03.35	39,070.33	11,908.53	**42 44 01.46**	**97 57 49.**
Arneson	66 41 32.71	32.40	319 59 16.34	35,395.97	10,788.59		
Niobrara	49 12 51.76	51.73	189 15 35.18	36,139.06	11,015.08		
Covell	64 05 35.83	35.87	73 22 04.13	29,704.52	9,081.20	**42 49 53.77**	**97 56 31.**

TABLE VII.—*Tabulated results of secondary triangulation from Running Water Base, South Dakota, to Blair, Nebraska.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first, in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
North Base	84 47 40.48	39.86	36 04 26.16	14,101.53	4,298.11		
South Base	83 33 18.40	18.37	249 36 28.94	15,957.15	4,863.70		
Lost Creek	61 39 02.44	01.77	131 17 46.91	8,556.66	2,609.49	42 46 56.68	97 54 03.94
Kelly	91 32 54.36	55.39	267 38 14.45	8,463.33	2,579.60		
North Base	51 35 04.49	05.34	36 04 26.16	14,101.53	4,298.11	42 47 54.41	97 55 33.18
South Base	36 51 58.72	59.27	179 11 11.29	11,052.99	3,368.92	42 46 01.81	97 57 24.49
Kelley	91 35 58.40	59.08	289 58 06.34	16,080.87	4,901.40		
Lost Creek	38 31 31.01	30.56	148 31 54.57	21,022.40	6,407.57		
Covell	49 52 30.38	30.36	18 22 44.91	13,099.08	3,992.56	42 49 53.77	97 56 31.20
Niobrara	39 16 51.47	52.25	184 09 19.47	23,297.40	7,100.98		
Kelley	74 11 27.90	28.47	289 58 06.34	16,080.87	4,901.40	42 47 50.98	97 57 26.60
Lost Creek	66 31 39.72	39.28	43 28 44.69	24,438.45	7,448.77		
Covell	83 40 25.13	25.43	9 16 28.18	36,139.06	11,015.08		
Niobrara	53 58 56.84	58.52	243 14 33.70	53,326.23	16,253.69		
Santee	42 20 34.76	36.05	105 42 23.59	43,396.74	13,227.20	42 47 58.11	97 47 10.61
Santee	48 26 25.62	25.66	105 42 23.59	43,396.74	13,227.20		
Crovell	52 01 06.45	08.75	233 34 53.78	33,021.05	10,064.72		
Springfield	79 32 24.99	25.59	334 06 30.83	34,784.06	10,602.09	42 53 07.24	97 50 34.33
Springfield	58 15 38.72	38.81	334 06 30.83	34,784.06	10,602.09		
Santee	74 53 21.65	22.32	229 02 11.76	40,547.90	12,358.89		
Bon Homme	46 51 00.82	50 58.87	95 57 50.15	46,029.62	14,029.70	42 52 20.47	97 40 19.47
Santee	40 37 18.51	16.68	229 02 11.76	40,547.90	12,358.89		
Bon Homme	60 05 54.26	53.11	349 00 58.09	26,867.86	8,189.25		
Herrick	79 16 51.74	50.21	89 44 54.49	35,774.44	10,903.95	42 47 59.94	97 39 10.81
Bon Homme	89 44 11.84	13.34	349 00 58.09	26,867.86	8,189.25		
Herrick	50 42 31.72	31.91	219 44 16.74	42,191.18	12,859.75		
Lakeport	39 33 13.58	14.75	79 21 37.82	32,653.71	9,952.76	42 53 20.24	97 33 08.55
Herrick	51 45 14.28	13.77	219 44 16.74	42,191.18	12,859.75		
Lakeport	55 28 49.05	50.67	344 19 32.81	34,692.98	10,574.33		
Pit	72 45 54.28	55.56	91 35 02.12	36,397.07	11,093.72	42 47 50.29	97 31 02.84
Lakeport	47 02 25.67	23.85	344 19 32.31	34,692.98	10,574.33		
Pit	102 41 47.12	45.51	267 02 43.29	50,377.16	15,354.82		
Schmidt	30 15 49.36	50.64	117 26 12.66	67,154.25	20,468.43	42 48 15.38	97 19 48.03
Pit	39 37 53.91	53.05	267 02 43.29	50,377.16	15,354.82		
Schmidt	97 09 33.39	34.29	184 19 56.53	46,932.51	14,304.90		
Welby	43 12 31.95	32.66	47 33 01.62	73,005.71	22,251.93	42 55 57.63	97 19 00.38
Schmidt	99 15 17.78	17.73	184 19 56.53	46,932.51	14,304.90		
Welby	44 49 55.91	56.55	319 30 32.20	78,972.82	24,070.69		
Bow Creek	35 54 48.55	45.72	103 43 33.92	56,412.95	17,194.51	42 46 03.82	97 07 32.98
Welby	37 03 49.92	48.76	319 30 32.20	78,972.82	24,070.69		
Bow Creek	89 27 24.67	24.18	229 05 44.21	59,226.33	18,052.02		
Spirit Mound	53 28 47.26	47.06	102 41 20.16	98,263.70	29,950.50	42 52 26.44	96 57 31.90
Bow Creek	60 30 29.40	29.25	229 05 44.21	59,226.33	18,052.02		
Spirit Mound	67 10 47.02	47.09	342 01 45.37	65,144.39	19,855.83		
Ryan	52 18 43.67	43.66	109 46 04.53	68,983.83	21,026.08	42 42 14.28	96 53 02.74
Spirit Mound	55 59 48.89	48.85	342 01 45.37	65,144.39	19,855.83		
Ryan	67 47 40.30	39.30	229 52 27.79	64,982.78	19,806.57		
Johnson	56 12 33.18	31.85	106 12 32.52	72,572.43	22,119.88	42 49 07.40	96 41 56.12
Ryan	69 26 14.98	14.81	229 52 27.79	64,982.78	19,806.57		
Johnson	32 49 01.51	00.78	17 10 59.41	62,261.43	18,977.11		
Ionia	77 44 44.05	44.41	119 23 27.98	36,039.02	10,984.59	42 39 19.78	96 46 02.25
Johnson	55 52 41.77	40.93	17 10 59.41	62,261.43	18,977.11		
Ionia	61 21 24.28	21.98	258 29 34.62	57,969.17	17,668.84		
Westfield	62 45 58.02	57.09	141 24 07.37	61,454.21	18,731.07	42 41 13.31	96 33 21.77
Ionia	64 12 11.08	10.72	258 29 34.62	57,969.17	17,668.84		
Westfield	46 00 52.71	52.87	32 37 16.97	55,619.03	16,952.53		
Triloba	69 46 57.14	56.41	142 45 49.32	44,448.57	13,547.80	42 33 30.39	96 40 02.36
stfield	58 19 09.77	11.81	32 37 16.97	55,619.03	16,952.53		
oba	33 09 11.12	11.79	245 41 57.63	47,347.19	14,431.29		
l	88 31 33.51	36.40	154 20 04.58	30,427.03	9,274.07	42 36 42.45	96 30 25.34
oba	75 36 34.44	32.72	245 41 57.63	47,347.19	14,431.29		
ll	37 54 40.35	39.27	27 53 48.68	50.017.01	15,245.05		
ınd Cap	66 28 48.74	48.01	141 21 29.48	31,727.75	9,670.53	42 29 25 68	96 35 37.66
l	42 21 09.87	11.08	27 53 48.68	50,017.01	15,245.05		
ınd Cap	55 24 29.56	28.26	263 14 45.86	34,007.90	10,365.51		
erson	82 14 20.13	20.66	165 34 11.13	41,555.36	12,665.96	42 30 04.95	96 28 06.87
ınd Cap	71 23 22.40	21.35	263 14 45.86	34,007.90	10,365.51		
erson	73 30 48.22	48.32	9 49 01.89	56,054.77	17,085.34		
rd	35 05 51.18	50.33	154 41 45.71	56,715.90	17,286.85	42 20 59.31	96 30 14.14
rson	58 00 30.94	32.47	9 49 01.89	56,054.77	17,085.34		
d	52 38 25.43	24.48	242 26 00.69	46,496.27	14,171.94		
eants	74 21 03.25	03.05	136 53 14.16	46,269.71	14,102.88	42 24 31.50	96 21 04.78
d	68 31 34.56	34.57	242 26 00.69	46,496.27	14,171.94		
eants	56 44 24.62	24.90	6 47 45.80	52,356.49	15,958.11		
nebago	55 44 00.82	00.44	131 02 49.87	46,500.12	14,173.11	42 15 57.93	96 22 27.17

TABLE VII.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Sargeants	67 36 08.41	09.46	6 47 45.80	52, 356.49	15, 958.11		
Winnebago	66 32 32.27	31.89	253 19 22.47	67, 458.50	20, 561.17		
Hedges	45 51 18.05	18.65	119 20 20.08	66, 932.32	20, 400.78	42 19 08.27	96 08 07.10
Hedges	46 33 03.55	02.24	73 29 01.18	67, 458.50	20, 561.17		
Winnebago	89 52 31.09	31.48	343 11 53.95	71, 049.52	21, 655.70		
Blackbird	43 34 25.37	26.28	206 49 23.79	97, 866.53	29, 829.45	42 04 45.93	96 17 54.86
Hedges	60 07 58.10	59.11	26 55 58.56	97, 866.53	29, 829.45		
Blackbird	39 01 23.90	22.31	245 50 46.52	85, 963.78	26, 201.52		
Grant	80 50 38.55	38.58	146 53 04.15	62, 414.99	19, 023.92	42 10 32.11	96 00 33.36
Blackbird	97 01 38.24	39.85	245 50 46.52	85, 963.78	26, 201.52		
Grant	29 18 03.39	04.02	36 44 20.78	105, 902.20	32, 278.70		
Sandig	53 40 14.95	16.13	162 54 43.11	52. 220.87	15, 916.78	41 56 32.87	96 14 31.41
Blackbird	69 54 18.34	19.60	342 52 26.95	52, 220.87	15, 916.78		
Sandig	73 47 49.64	51.62	236 42 35.05	82, 845.71	25, 251.14		
Kennebec	36 17 48.30	48.78	93 10 38.45	84, 711.80	25, 819.92	42 04 01.07	95 59 13.37
Kennebec	55 26 37.79	35.74	56 52 49.34	82, 845.71	25, 251.14		
Sandig	67 59 23.24	20.96	304 41 56.50	81, 756.72	24, 919.22		
Mormon	56 34 03.15	03.30	181 25 52.25	92, 036.10	28, 052.35	41 48 52.12	95 59 43.85
Mormon	48 51 07.92	07.92	124 51 48.95	81, 756.72	24, 919.22		
Sandig	51 22 55.01	55.13	356 04 51.95	62, 559.35	19, 067.92		
Tekamah	79 45 57.14	56.95	255 51 26.85	64, 911.37	19, 784.81	41 46 16.27	96 13 34.99
Mormon	93 27 13.63	12.76	76 00 40.72	64, 911.37	19 784.81		
Tekamah	35 37 15.76	13.46	291 28 40.56	83, 461.10	25, 438.71		
Taylor	50 55 33.21	33.78	162 35 35.54	48, 697.22	14, 842.78	41 41 13.10	95 56 31.48
Tekamah	62 20 36.90	36.36	291 28 40.56	83, 461.10	25, 438.71		
Taylor	36 21 07.82	07.70	75 18 53.77	74, 785.07	22, 794.28		
Herman	81 18 15.75	15.94	173 50 04.39	50, 046.51	15, 254.04	41 38 04 70	96 12 24.06

TABLE VIII.—*Tabulated results of secondary triangulation from Blair, Nebr., to Fort Leavenworth, Kans.*

[Azimuths and distances are in the order of stations, first to second, second to third, and third to first in each triangle.]

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Bench	32 16 43.97	43.04	190 45 20.59	22, 490.54	6, 855.06	41 33 11.12	96 07 45.58
East Base	79 08 57.94	55.26	89 54 52.56	12, 902.60	3, 932.68	41 36 49.41	96 06 50.33
West Base	68 34 23.34	21.70	338 27 21.47	23, 728.48	7, 232.38	41 36 49.19	96 09 40.18
East Base	95 50 12.82	10.75	10 45 57.25	22, 490.54	6, 855.06		
Bench	46 11 27.90	27.35	144 33 53.24	36, 476.09	11, 117.81		
Herman	37 49 19.28	21.90	286 41 26.36	26, 467.31	8, 067.16	41 38 04.65	96 12 24.07
East Base	104 54 19.74	20.14	106 45 08.05	26, 467.31	8, 067.16		
Herman	43 32 38.43	36.83	330 14 03.26	48, 879.98	14, 898.48		
Blair	31 33 04.58	03.03	181 50 37.97	34, 846.27	10, 621.05	41 31 05.32	96 07 05.09
Herman	75 06 15.84	13.94	330 14 03.26	48, 879.98	14, 898.48		
Blair	67 41 26.56	24.98	217 59 00.21	78, 119.35	23, 810.56		
Taylor	37 12 21.13	21.08	75 18 22.26	74, 785.07	22, 794.28	41 41 13.15	95 56 31.47
Blair	57 08 19.85	20.93	217 59 00.21	78, 119.35	23, 810.56		
Taylor	50 31 27.92	27.63	347 34 33.27	68, 866.22	20, 990.24		
Loveland	72 20 11.75	11.44	95 16 30.43	63, 283.34	19, 288.59	41 30 08.67	95 53 16.76
Blair	44 34 26.73	27.80	275 07 21.46	63, 283.34	19, 288.59		
Loveland	64 18 25.35	25.04	30 58 05.18	46, 040.21	14, 307.24		
Douglas	71 07 06.80	07.16	139 47 28.28	60, 269.49	18, 369.97	41 23 30.89	95 58 33.65
Loveland	35 45 53.75	52.80	30 58 05.18	46, 940.21	14, 307.24		
Douglas	85 30 50.20	50.35	296 25 25.89	32, 100.22	9, 784.06		
Crescent	58 43 17.90	16.85	175 12 51.86	54, 754.90	16, 689.14	41 21 09.58	95 52 16.73
Douglas	57 05 14.91	15.14	296 25 25.89	32, 100.22	9, 784.06		
Crescent	73 49 06.02	06.68	42 40 28.24	35, 655.89	10, 867.82		
Omaha	49 05 38.62	38.18	173 31 20.99	40, 790.08	12, 432.71	41 16 50.46	95 57 27
Omaha	50 51 08.93	08.53	222 36 59.25	35, 655.89	10, 867.82		
Crescent	52 59 45.92	44.30	349 40 43.94	28, 479.72	8, 680.54		
Council	76 09 08.44	07.17	93 32 20.76	29, 326.81	8, 938.73	41 16 32.75	95 51 91
Omaha	65 23 32.84	30.81	273 28 07.85	29, 326.81	8, 938.73		
Council	76 12 48.29	49.14	16 19 31.52	42, 930.99	13, 085.25		
Bellevue	38 23 42.58	40.05	158 54 01.35	45, 859.26	13, 977.78	41 09 47.79	95 53 06
Omaha	45 15 31.80	30.38	338 51 38.66	45, 859.26	13, 977.78		
Bellevue	49 13 41.21	39.06	208 07 40.41	32, 673.40	9, 958.76		
Bluffs	85 30 52.78	50.56	113 40 43.87	34, 836.35	10, 618.02	41 14 32.44	95 50 43
Bellevue	106 43 06.69	05.66	208 07 40.41	32, 673.40	9, 958.76		
Bluffs	36 11 17.43	16.05	351 58 37.11	51, 883.67	15, 814.00		
Henton	37 05 38.82	38.29	134 54 01.00	31, 985.87	9, 749.21	41 06 04.82	95 49 85
Bellevue	44 59 51.20	58.60	314 50 46.15	31, 985.87	9, 749.21		
Henton	91 32 01.71	01.91	43 21 59.01	32, 877.22	10, 020.89		
Platte	43 27 59.24	59.49	179 50 45.99	46, 479.12	14, 166.71	41 02 08.56	95 53 43

TABLE VIII.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	″	° ′ ″	*Feet.*	*Metres.*	° ′ ″	° ′ ″
Henton	51 35 04.99	03.02	43 21 59.01	32,877.22	10,020.89		
Platte	94 41 36.31	36.34	318 00 21.94	46,400.23	14,142.66		
Quarry	33 43 20.96	20.64	171 48 08.02	59,021.51	17,989.59	40 56 27.62	95 47 10.92
Platte	39 02 59.74	03 01.97	318 00 21.94	46,400.23	14,142.66		
Quarry	78 45 50.30	49.90	59 18 57.23	33,050.97	10,073.85		
Calumet	62 11 08.82	08.13	177 03 46.70	51,455.88	15,683.61	40 53 40.80	95 53 21.02
Quarry	71 44 44.28	44.08	59 18 57.23	33,050.97	10,073.85		
Calumet	55 47 13.14	13.56	295 02 08.47	39,580.58	12,064.05		
Thurman	52 28 02.87	02.36	167 35 16.26	34,465.82	10,505.09	40 50 55.04	95 45 34.40
Calumet	53 08 11.45	11.87	295 02 08.47	39,580.58	12,064.05		
Thurman	45 03 29.60	30.44	70 03 43.30	31,993.85	9,751.64		
Jones	81 48 16.44	17.69	168 11 09.85	28,305.27	8,627.37	40 49 07.05	95 52 05.56
Thurman	81 49 25.07	23.47	70 03 43.30	31,993.85	9,751.64		
Jones	43 34 45.18	44.20	293 34 11.81	38,852.07	11,842.00		
Pugh	54 35 53.45	52.33	168 15 06.62	27,057.88	8,247.17	40 46 33.28	95 44 22.71
Jones	53 40 08.92	08.70	293 34 11.81	38,852.07	11,842.00		
Pugh	87 00 44.77	45.48	26 38 28.59	49,397.36	15,056.18		
Otoe	39 19 05.95	05.82	167 16 15.31	61,233.55	18,663.82	40 39 16.90	95 49 10 08
Pugh	41 25 43.63	42.77	26 38 28.59	49,397.36	15,056.18		
Otoe	52 38 51.38	50.89	259 14 12.12	32,768.36	9,987.71		
McCracken	85 55 26.65	26.34	165 14 10.78	39,366.35	11,998.75	40 40 17.16	95 42 12.33
Pugh	30 07 45.65	45.36	345 12 45 71	39,366.35	11,998.75		
McCracken	115 38 31.53	31.09	49 35 39.54	35,128.99	10,707.22		
City	34 13 43.72	43.55	195 18 10.00	63,092.73	19,230.44	40 36 32.01	95 47 59.14
McCracken	76 00 11.28	11.66	49 35 39.54	35,128.90	10,707.22		
City	62 34 00.54	01.08	292 05 54.87	51,512.57	15,700.89		
Hamburg	41 25 47.52	47.26	153 38 24.49	47,118.96	14,361.73	40 33 20.06	95 37 40.83
City	39 58 02.04	02.18	292 05 54.87	51,512.57	15,700.89		
Hamburg	78 26 13.19	12.69	33 46 24.27	37,617.70	11,465.77		
Peru	61 35 45.42	45.13	152 07 43.37	57,374.13	17,487.48	40 28 10.98	95 42 11.39
Hamburg	56 51 59.28	58.71	33 46 24.27	37,617.70	11,465.77		
Peru	67 26 52.80	52.27	281 10 20.88	38,138.61	11,624.54		
Phelps	55 41 09.04	09.02	156 56 44.04	42,061.50	12,820.30	40 26 57.68	95 34 07.44
Peru	52 43 15.05	14.76	281 10 20.88	38,138.61	11,624.54		
Phelps	42 42 26.50	26.80	58 33 08.06	30,483.31	9,291.23		
Brownville	84 34 18.43	18.44	153 55 11.63	25,984.24	7,919.92	40 24 20.39	95 39 43.50
Phelps	79 04 21.06	19.70	58 33 08.06	30,483.31	9,291.23		
Brownville	48 43 45.46	45.15	287 13 15.29	37,879.98	11,545.71		
Langdon	52 11 56.10	55.15	159 30 13.43	28,996.41	8,838.03	40 22 29.30	95 31 56.12
Brownville	44 08 55.92	56.51	287 13 15.29	37,879.98	11,545.71		
Langdon	89 43 47.90	47.69	17 34 30.40	36,604.05	11,156.81		
St. Deroin	46 07 15.38	15.80	151 25 42.32	52,551.70	16,017.61	40 16 44.45	95 34 18.72
Langdon	50 08 10 48	09.51	17 34 30.40	36,604.05	11,156.81		
St. Deroin	58 49 00.75	01.33	256 21 59.53	29,706.59	9,054.48		
Nishne	71 02 50.00	49.16	147 28 49.68	33,110.47	10,091.98	40 17 53.47	95 28 06.15
St. Deroin	55 52 36.25	35.60	256 21 59.53	29,706.59	9,054.48		
Nishne	39 52 11.38	11.36	36 33 49.05	24,716.21	7,533.43		
Devoir	84 15 14.18	13.04	132 16 33.29	19,139.45	5,833.65	40 14 37.26	95 31 16.01
Nishne	76 43 51.89	51.61	36 33 49.05	24,716.21	7,533.43		
Devoir	67 18 57.25	57.16	283 50 43.55	40,973.25	12,488.53		
Craig	35 57 11.71	11.23	139 53 26.05	38,840.69	11,838.53	40 13 00.05	95 22 43.21
Devoir	47 11 00.57	00.42	283 50 43.55	40,973.25	12,488.53		
Craig	71 34 08.70	08.80	32 22 05.84	34,282.02	10,449.07		
Arago	61 14 50.46	50.78	151 04 42.61	44,338.24	13,514.17	40 08 13.84	95 26 39.51
Craig	63 39 02.14	02.30	32 22 05.84	34,282.02	10,449.07		
Arago	88 15 21.45	21 33	300 34 54.90	65,235.80	19,883.69		
Napier	28 05 37.34	36.37	148 48 16.49	72,765.62	22,178.76	40 02 45.22	95 14 37.39
Arago	27 48 21.04	19.70	300 34 54.90	65,235.80	19,883.69		
Napier	48 55 24.20	24.13	71 47 15.70	31,265.55	9,529.65		
Nemcha	103 16 16 25	16.17	148 26 54.00	50,526.13	15,400.22	40 01 08.48	95 20 59.11
ier	56 36 22 82	22.63	71 47 15.70	31,265.55	9,529.65		
eha	62 56 06.56	06 05	314 39 16.28	30,004.40	9,145.26		
te Cloud	60 27 31.44	31.32	195 09 43.82	32,001.89	9,754.09	39 57 39.99	95 16 25.02
ier	48 53 28.57	29.27	15 10 53.00	32,001.89	9,754.09		
te Cloud	64 09 01.10	01.12	259 18 44.99	26,202.76	7,986.53		
st City	66 57 28.88	29.61	146 19 47 04	31,296.66	9,539.14	39 58 27.88	95 10 54.30
te Cloud	51 31 52.19	51.79	259 18 44.99	26,202.76	7,986.53		
st City	86 33 49,65	49.19	352 48 28.18	30,716.09	9,362.18		
out	41 54 17.89	19.02	130 54 40.76	39,160.91	11,936.14	39 53 26.71	95 10 04.96
st City	32 03 23.57	24.26	352 48 28.18	30,716.09	9,362.18		
kout	53 27 31.06	31.23	226 16 31.10	16,352.89	4,984.31		
ne	94 29 04.84	04.51	140 47 12 92	24,753.94	7,544.93	39 55 18.39	95 07 33.29
kout	71 29 03.12	02.04	226 16 31.10	16,352.89	4,984.31		
ne	71 27 03.59	03.67	334 51 04.71	25,727.23	7,841.59		
rs	37 03 54.48	54.29	117 48 40.29	25,722.28	7,840.08	39 51 28.21	95 05 13.09
ne	60 15 59.90	59.25	334 51 04.71	25,727.23	7,841.59		
rs	64 54 07 81	07.35	219 46 42.02	27,328.50	8,329.65		
vay	54 49 55.53	53.40	94 38 59.36	28,500.59	8,686.90	39 54 55.71	95 01 28.70

TABLE VIII.—*Tabulated results of secondary triangulation, etc.*—Continued.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Distance.		Latitude.	Longitude.
	° ′ ″	′ ″	° ′ ″	Feet.	Metres.	° ′ ″	° ′ ″
Meers	59 35 56.64	58.03	219 46 42.02	27,328.50	8,329.65		
Nodaway	57 32 34.90	34.05	342 16 31.82	26,487.99	8,073.47		
Fox	62 51 28.27	27.92	99 26 10.19	25,918.22	7,898.28	39 50 46.35	94 59 45.32
Nodaway	57 11 30.08	28.68	342 16 31.82	26,487.99	8,073.47		
Fox	77 55 11.92	11.39	240 12 49.57	31,545.49	9,614.98		
Amazonia	44 53 20.99	19.93	105 09 54.69	36,701.39	11,186.48	39 53 21.07	94 53 54.10
Fox	50 51 40.14	40.65	240 12 49.57	31,545.49	9,614.98		
Amazonia	75 29 46.51	46.89	344 46 47.81	30,381.64	9,260.24		
St. Joe	53 38 31.26	32.46	111 09 20.69	37,922.43	11,558.65	39 48 31.34	94 52 11.90
Fox	48 59 50.67	50.69	291 04 30.29	37,922.43	11,558.65		
St. Joe	62 35 59.52	59.55	48 33 21.07	30,780.23	9,381.73		
Wathena	68 24 09.35	09.76	160 06 02.21	36,210.22	11,036.78	39 45 09.89	94 57 07.31
St. Joe	53 26 46.87	45.85	48 33 21.07	30,780.23	9,381.73		
Wathena	67 08 17.82	16.24	295 38 28.36	28,721.17	8,754.13		
Kings Knob	59 25 00.33	24 57.91	175 06 58.08	32,945.40	10,041.67	39 43 06.93	94 51 35.96
Wathena	88 28 07.73	06.99	295 38 28.36	28,721.17	8,754.13		
Kings Knob	37 13 50.95	49.85	78 28 10.27	35,354.20	10,775.86		
Anderson	54 18 02.56	03.16	204 05 23.93	21,397.76	6,521.96	39 41 56.86	94 58 59.13
Wathena	56 38 55.38	55.54	295 38 28.36	28,721.17	8,754.13		
Kings Knob	76 27 45.65	44.29	39 14 15.82	32,863.33	10,016.65		
Kenmoor	46 53 21.86	20.17	173 18 05.85	38,249.30	11,658.28	39 38 55.29	94 56 01.70
Anderson	39 56 02.02	02.38	322 55 31.14	23,021.36	7,016.85		
Kenmoor	91 12 50.81	51.90	51 44 32.51	19,624.64	5,981.53		
Halls	48 51 05.04	05.72	182 51 21.09	30,565.67	9,316.33	39 36 55.15	94 59 18.61
Anderson	42 13 24.46	23.64	2 51 33.57	30,565.67	9,316.33		
Halls	57 23 21.92	22.39	125 27 58.70	20,833.26	6,349.92		
Geary	80 23 14.31	13.97	225 02 26.29	26,113.77	7,959.40	39 38 54.56	95 02 55.52
Halls	48 48 33.63	33.50	125 27 58.70	20,833.26	6,349.92		
Geary	90 10 39.91	40.54	35 36 20.92	23,890.33	7,281.71		
Atchison	41 00 45.26	45.87	256 35 13.53	31,746.85	9,676.35	39 35 42.56	95 05 53.39
Geary	43 21 52.39	53.35	35 36 20.92	23,890.33	7,281.71		
Atchison	91 49 13.73	14.26	307 23 41.96	23.274.31	7,093.94		
Gordon	44 48 52.75	52.39	172 15 04.75	33,878.79	10,326.16	39 33 22.79	95 01 57.13
Atchison	54 13 12.90	09.89	307 23 41.96	23,274.31	7,093.94		
Gordon	67 11 11.47	09.38	60 15 02.95	22,122.43	6,742.86		
Snyder	58 35 41.14	40.73	181 36 46.14	25,135.84	7,661.33	39 31 34.23	95 06 02.24
Gordon	87 43 31.26	30.49	60 15 02.95	22,122.43	6,742.86		
Snyder	47 42 23.42	24.65	287 54 51.60	31,499.54	9,600.97		
Reese	44 34 04.08	04.86	152 32 59.73	23,318.98	7,107.56	39 29 58.30	94 59 39.80
Snyder	32 39 46.54	45.40	287 54 51.60	31,499.54	9,600.97		
Reese	87 24 08.74	09.04	20 34 45.78	19,642.82	5,987.08		
Oak Mills	59 56 06.85	05.56	140 37 44.22	36,359.02	11,082.13	39 26 56.54	95 01 07.91
Reese	49 49 08.50	08.02	20 34 45.78	19,642.82	5,987.08		
Oak Mills	52 21 00.47	20 59.02	252 54 48.86	15,352.22	4,679.31		
Iatan	77 49 54.60	52.96	150 46 40.72	15,909.75	4,849.25	39 27 41.08	94 56 00.81
Oak Mills	67 55 05.91	06.20	252 54 48.86	15,352.22	4,679.31		
Iatan	67 22 58.79	59.52	5 33 48.21	20,225.50	6,164.68		
Kickapoo	44 41 54.75	54.28	140 51 38.04	20,147.98	6,141.05	39 24 22.18	94 58 26.79
Iatan	48 46 38.34	38.27	5 33 48.21	20,225.50	6,164.68		
Kickapoo	87 28 06.61	05.19	273 01 37.57	21,997.27	6,704.71		
Weston	43 45 17.30	16.54	136 49 51.78	29,217.16	8,905.31	39 24 10.55	94 53 45.96
Kickapoo	43 33 56.36	56.13	273 01 37.57	21,907.27	6,704.71		
Weston	52 18 40.16	40.27	40 45 54.91	15,240.27	4,645.19		
Sheridan	84 07 23.78	23.60	136 37 10.94	17,499.36	5,333.76	39 22 16.45	94 55 52.67

EXTRA STATIONS.

Station.	Observed angle.	Adjusted angle.	Azimuth.	Feet.	Metres.	Latitude.	Longitude.
Councils	93 03	18.00	169 41 27.93	28,479.72	8,680.54		
Crescent	40 40	57.00	30 21 40.94	39,270.98	11,969.67		
U. S. C. and G	46 15	45.00	256 34 34.04	25,694.95	7,831.75	41 15 33.94	95 56 37.22
Councils	92 32	38.00	169 41 27.93	28,479.72	8,680.54		
Crescent	40 55	57.00	30 36 40.94	39,208.07	11,950.51		
High School	46 31	25.00	257 05 13.44	25,713.27	7,837.33	41 15 36.11	95 56 [illegible] 14

SECTION I.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, FROM THREE FORKS TO FORT BENTON, MONTANA.

[Abbreviations: △ = Secondary triangulation station. R. B. = Right bank. L. B. = Left ban

South Base is in the town of Gallatin, Mont., between the Gallatin and Mad n rivers, and on L. B. of Moss Creek, and east of Main street; is 1,053 feet southwes of the northeast corner of sec. 20, T. 2 N., R. 2 E.

North Base is on R. B. of the river formed by the junction of the Madison d Jefferson, on a low bank, in timber, and about 120 feet from water's edge; is al t 400 feet west of the south end of rocky plateau.

Gallatin is on R. B., one-half of a mile east of river and one-half of a mile northeast of water tank at railroad station Gallatin; is on first high land northeast of water tank; there is higher land 600 feet north.

Campbell is on L. B., three-eighths of a mile back from river and 1 mile north of Fannie Campbell's ranch; is on west end of a rocky point, and is the highest land in vicinity. △ is marked by a copper bolt, three-eighths of an inch in diameter and 6 inches long, leaded in the natural rock.

Cedar Hill is on R. B., one-half of a mile east of river, and 1¾ miles north of railroad station Gallatin; is on a high point covered with small cedar trees, and quite prominent; is very rocky, quite abrupt towards the west; marked by a copper bolt and letters U. S.

Huntley is on R. B., back 2 miles from a point 4 miles from its head; 4 miles south of railroad station Magpie, 2 miles above Huntley & Clark's ranch; is on middle one of 3 similar hills; is rocky, also, the hill to the northeast. The one to the southwest is grassy. A road crosses divide 800 feet southwest. Is marked by copper bolt.

Spring is on L. B., three-eighths of a mile west of river and 3 miles from its head; is on first bluff, very steep to the east, but slopes gradually to the west. △ is near north end of rocky bluff and on highest part; is within 3 feet of edge of bluff to the east; is marked by copper bolt.

Clark is on R. B., 1¼ miles back from river at a point 2¼ miles above railroad station Magpie, 1 mile east from Huntley & Clark's ranch; is on first bluff from river, which extends about 1,200 feet east and west, and is very steep to south. The △ is 30 feet from edge of bluff to southeast.

Beattie is on L. B., 2 miles from river at a point opposite Beattie's ranch; is on north end of ridge which slopes gradually to east, but very abrupt to west; is the highest land in vicinity, excepting a ridge one-half of a mile north.

Sawyer is on L. B., back from river three-eighths of a mile from a point 1¼ miles below railroad station Magpie; on first bluff, very rocky, shows lead stain, several north showing lead stain but none south. Is the highest land within 1¼ miles.

Magpie is on R. B., 2¼ miles N. 60° E. from Magpie railroad station, and same distance from river at a point where N. P. R. R. strikes bluff. △ is on a narrow, grassy ridge, extending northeast and southwest; is 800 feet north of a road in bottom of a ravine.

Pinnacle is on L. B., 1¼ miles above railroad station Painted Rock, one-half of a mile northwest from Carolus' ranch; is on east end of a high plateau hill, the highest land in vicinity. △ is marked by copper bolt.

Carolus is on R. B., 2¼ miles northeast from Carolus' ranch; is on a grassy ridge and 40 feet from south edge; is the highest land within 2¼ miles of △.

Painted Rock is on L. B., 3½ miles below railroad station Painted Rock; is on a very high and prominent hill, very steep to water's edge. △ is close to south edge.

Lone Bush is on R. B., 1¼ miles back from river, and 2 miles northeast of Mammoth Springs; is on a long grassy hill with a lone bush 50 feet southwest of station; the hill is quite prominent. The land 600 feet northeast of △ is the highest in vicinity. Is marked by a copper bolt.

Toston is on R. B., 2¼ miles due east of the town of Toston, Mont., on first grassy hill east, and is the highest land within 5 miles of Toston.

Dougherty is on L. B., 2 miles back from the river at the town of Toston, Mont., on the ranch of John E. Dougherty, three-eighths of a mile northwest of his house; 600 feet west of the northeast corner of the NW. ¼ of the NE. ¼ of sec. 28, T. 5 N., R. 2 E.

Howard is on L. B., 1 mile from river at a point 4 miles below Toston, Mont., on a ridge 25 feet high, three-eighths of a mile north of "Crazy" Howard's house; a long, narrow ridge of same elevation between △ and Howard's house.

Reeves is on R. B., 2 miles from river at a point 7 miles, by rail, above Townsend, Mont.; 1¼ miles N. 82° E. of George P. Reeves' ranch, on a grassy ridge 150 feet high; higher land 600 feet southeast; land much higher to east and northeast.

Hossfeld is on L. B., on a rocky point one-half of a mile north of Hossfeld's house, and one-half mile back from river, on first hill; is said to be in NE. ¼ of SW. ¼ of sec. 20, T. 6 N., R. 2 E.; marked by a copper bolt.

Deep Creek is on R. B., 4 miles back from river opposite △ Hossfeld, 3½ miles south-st of Townsend, Mont., one-half of a mile south of stage road to Castle; on R. B. of ;ep Creek, three-eighths of a mile from valley; higher land 1 mile northeast, but has lars on south. Hill on which △ is located is grassy.

Bridge is on L. B., one-quarter of a mile northwest of Northern Pacific Railroad idge at Townsend, Mont., and 200 feet west of track, on plateau; is in northeast rner of NE. ¼ of sec. 25, T. 7 N., R. 1 E.

Marks is on R. B., on west edge of a plateau, 6 miles northeast of Townsend, Mont., d 1 mile north of Marks' ranch, 280 feet west of Catholic cemetery, and 20 feet east edge of plateau.

Reed is on L. B., 130 feet west of edge of bluff. 1¼ miles above mouth of Eight-mile ugh, one-half of a mile N. 80° E. to Henry Reed's house on island.

Duck Creek is on R. B., on a grassy hill 3¼ miles east and one-half mile south of Pickering Ferry; highest land in vicinity; is 450 feet S. 11° 15′ E. of northwest corner of sec. 15, T. 8 N., R. 2 E.

Beaver Creek is on L. B., on a knoll of a long ridge; land 600 feet northwest is as high as station and gradually gets higher to northwest; is 2¼ miles northwest from Pickering Ferry and same distance southwest of Blake Ferry. Albert Filson's house is three-quarters of a mile N. 50° 39′ E.

Confederate is on R. B., on a ridge running north and south on R. B. of Confederate Creek, and 1 mile west, 3 miles northeast of Pickering Ferry, 1 mile west of Morgan's ranch, 1 mile north of Johnny Thomas' ranch; highest land in vicinity.

Geary is on R. B., 2 miles from river at a point 2 miles below Blake Ferry; is on a knoll in William Geary's field, and 900 feet southwest of his house; highest land in field. △ is near center of the SE. ¼ of the NE. ¼ of sec. 12, T. 9 N., R. 1 E.

Squires is on L. B., on east end of a chalk limestone hill, 700 feet long east and west; 1 mile northwest from Squires house, three-quarters of a mile south of A. McMillan's house; is in northwest corner of sec. 21, T. 9 N., R. 1 E.

Blackwell is on R. B., about 4 miles northeast of Thomas Cooney's house, on a level plateau about 1¼ miles northeast of Joe Blackwell's house, 250 feet south from edge of Avalanche Gulch and 30 feet north of an old road.

Degan is on L. B., on east end of a narrow rocky ridge, 5 miles above Canyon Ferry, one-half of a mile west of Degan's ranch, and one-quarter of a mile back from river; land back of station is much higher. △ is marked by a copper bolt.

Maxwell is on R. B., about 4¼ miles N. 36° E. of the town of Canyon Ferry, Mont., on the middle one of three high, wooded hills, about 1 mile northeast of Maxwell's house. △ is marked by a copper bolt.

Canyon Ferry is on L. B., on a rocky ridge running nearly east and west and the highest point within 2 miles. △ is about 2 miles N. 65° W. of the town of Canon Ferry. Is marked by a copper bolt leaded in natural rock 2 feet above general surface.

Stubbs is on L. B., on north end of a grassy ridge, 1¾ miles west of the river, at Stubbs Ferry, about 170 feet south of a fence and the road to Helena, Mont.

Fuller is on R. B., on middle one of three ridges of about same elevation, running northwest and southeast, about 3¼ miles east of Stubbs Ferry and same distance north from river at French Bar. Ridge is very rocky and is just seen over ridge in front from △ Stubbs. Marked by a copper bolt.

Prickly Pear is on L. B., and on L. B. of Prickly Pear Creek, about one-half of a mile west of a point 1 mile above mouth of creek; is on a grassy-topped hill; shale rock crops out in places; land 1,000 feet north is higher. Marked by a copper bolt.

Hilger is on L. B., on a high plateau-topped hill, about 4 miles south of N. Hilger's ranch; is 20 feet from south edge of hill; large bowlder just southwest of △. Highest hill on L. B. within 8 miles. Marked by a copper bolt.

El Dorado is on R. B., back about 2½ miles from the abandoned placer mine at El Dorado Bar. It is on a mountain 600 feet high to left of left branch of a gulch emptying into river at El Dorado Bar. There is a higher mountain 1 mile south. West face of mountain, on which △ is located, is of white rock almost to base. Marked by a copper bolt.

B. T. Mountain is on L. B., on a high mountain 5 miles north of N. Hilger's ranch, and 1½ miles from river. △ is not located on highest part, but 300 feet southeast. △ is 100 feet from its southeast point. Rock into which copper bolt is leaded is just flush with surface.

American is on R. B., on south peak of a two-peaked mountain, 3 miles from river as measured along large ravine running along south side of mountain and emptying into river at American Bar. North peak of mountain is wooded; south peak is bare. Marked by a copper bolt.

Willow Creek is on R. B., on a very high ridge running north and south between Willow Creek and Cottonwood Creek, and 4½ miles back from river. △ is not on highest part of hill, but on a grassy spot 40 feet in front of a rocky ridge 15 feet higher than station. Marked by a copper bolt in a bowlder.

Ox Bow is on L. B., on a very prominent, sharp, rocky point 1,700 feet high, 1 mile back from river at Mitler's Island. △ is marked by a copper bolt in highest par Highest hill within 3 miles.

Mitler is on R. B., very high hill, wooded on west to within three-eighths of a mi of station, is 3¾ miles back from river at Mitlers Island. △ is marked by a copp bolt in highest part of hill. Higher land 2 miles northwest.

Wolf Creek is on L. B., on south end of a rocky point three-eighths of a mile nor of Wolf Creek, and 3 miles west from river at its mouth, three-quarters of a mi northeast from the town of Wolf Creek, on first rocky knob from south end; high knobs farther north. Marked by a copper bolt.

Rock Creek is on L. B., on a sharp, rocky hill, 3 miles above Craig, Mont.; a lor

narrow ridge on east and north side of station three-eighths of a mile distant. There is a sharp hill fully as high 700 feet west. △ is marked by a copper bolt.

Wagner is on R. B., on a low, grassy hill 1½ miles from the river at the town of Craig, Mont.; is three-eighths of a mile north of Wagner Creek. There is a long, rocky ridge running southwest from station to a log schoolhouse. △ is marked by a copper bolt.

Craig is on L. B., on a rocky ridge, 1½ miles from river, at a point 3½ miles below Craig, Mont., or one-half of a mile below tunnel No. 3 on Great Northern Railroad. Ridge is long and even-topped, standing by itself, highest land within 2 miles. Marked by a copper bolt.

Stickney is on R. B., on a rocky knob on north end of ridge, about 1¼ miles from nearest point on river and 3½ miles from R. M. Stickney's ranch. There is no higher land within 1 mile of △. Rock in which copper bolt was leaded being poor, a reference bolt was set 7.37 feet S. 53° 44′ E.

Sugar Loaf is on L. B., on a very high, dark mountain standing by itself, 3 miles from river at Mid Cañon railroad station. There is no higher land within 5 miles. △ is on north end of rocky top, marked by a copper bolt.

Hardy is on L. B., back from river, about 2¾ miles from railroad station Hardy. △ is located on a rocky knob about half way up a long ridge, wooded to the north, and very high, and having a rocky point on south end. △ is on first rocky point below woods; several points south of △, but none so high. Marked by a copper bolt.

Sheep Creek is on R. B., on north end of a high, rocky mountain, 4 miles from river at a point 2 miles below railroad station Hardy, Mont. △ is on a rocky knob; mountain is higher 1¼ miles to southeast. Marked by a copper bolt.

Cascade is on L. B., on southeast part of a plateau 150 feet high, 1¼ miles northwest of the town of Cascade, Mont. △ is 150 feet from east edge, but not on highest part of plateau. Marked by a copper bolt.

St. Clair is on R. B., on a smooth, grassy ridge between Bird Creek and Missouri River, 3¾ miles from river at the town of Cascade, Mont., and three-quarters of a mile northwest from Rid Burmeister's house; on highest part of ridge; pile of stones 8 feet southeast of station.

Divide is on R. B., on a ridge between Bird Creek and Smith River, about 3¾ miles back from river at a point 1½ miles below mouth of Muddy Creek. Is on a knob on east side of ridge; a prairie-dog town east and north.

Muddy Creek is on L. B., on west end of a ridge, and about 1¼ miles east of Muddy Creek; a pile of rocks 400 feet west of station. △ is about one-half of a mile from river.

Ulm is on L. B., on a smooth, grassy, plateau hill, very low, 1 mile northwest of railroad station Ulm, Mont. Is first hill to northwest.

Wilson is on R. B., on a small plateau hill on main plateau, 1¾ miles southwest of David Wilson's house and three-quarters of a mile from river. There is a plateau hill east as high as where △ is, but is not connected to main plateau.

Antelope is on L. B., on Antelope Butte, about 5 miles east of Ulm, Mont. Butte is 20 feet higher than surrounding plateau. △ is on highest part of butte.

Epler is on L. B., three-eighths of a mile from river above the "Big Bend." Is 30 feet from southeast edge of plateau. The land is higher about 1,600 feet southwest of △.

Big Bend is on R. B., on north side of a long ridge, 3¼ miles from river at Big Bend and 4½ miles south from river at "Box Elder Park." Ridge is higher one-quarter of a mile south from △. There is a pile of rock 6 feet high on east end of ridge, one-half mile east of station.

Sand Coulée is on R. B., on grassy, round-topped, plateau hill, 1 mile east of river, 1½ miles south of Sand Coulée Creek. △ is on highest part of hill, and is the highest land within 2 miles; 150 feet east to wire fence; one-quarter of a mile east to rocky ravine.

Sun River is on L. B., on a level plateau, 2 miles from river, 1 mile southwest of railroad bridge across Sun River. △ is 150 feet from edge of slope on southeast, and 500 feet northwest of an old road.

Transfer is on L. B., on southeast part of plateau, 2 miles from river at the town of [...]at Falls, Mont. Is 150 feet from edge of plateau. Land is higher 800 feet west. [...]eau is northwest from town of Great Falls.

[...]eat Falls is on the R. B., on west end of a plateau ridge 2¾ miles east from the [...]r opposite the mouth of Sun River, five-eighths of a mile southeast of Rolfe's house; [...]her land 800 feet east of station.

[...]orth Great Falls is on L. B., on a high plateau, in the town of North Great Falls, [...]feet south of a large wedge-shaped two-story hotel, 120 feet west of edge of bluff.

[...]enry is on R. B., on a slight rise one-half of a mile east of J. L. Henry's house and 5¼ [...]s east of the town of Great Falls, Mont. Land is higher in vicinity of Henry's [...]e, and much higher 1¼ miles southwest.

[...]rter is on L. B., on a level plateau, 2½ miles from river at a point 8 miles below

town of Great Falls, 2½ miles southeast of Black Butte, three-eighths of a mile southeast of a frame house. △ is on highest land in vicinity.

Bromedy is on R. B., on a slight rise 1¾ miles from river, and the highest land within 3 miles. Is in NE. ¼ of section 31, T. 21 N., R. 5 E. There is a group of three houses three-quarters of a mile northeast.

Belt is on R. B., on north end of a plateau ridge, about 13 miles east of Great Falls, Mont., 2½ miles from river, and same distance west of Belt River; three-quarters of mile west of a coulée. Higher land one-half of a mile southwest.

Earley is on L. B., about 14 miles below the town of Great Falls, Mont., and 1½ miles from the river at the "Great Falls." Is on a rise about 300 feet east of a shanty owned by Mr. Earley, about 2 miles east to river.

Portage is on L. B., on a hill 2½ miles southeast of Portage section-house and 2 miles from river. Is the highest land in vicinity.

Sidney is on L. B., on a slight rise on a plateau, 1½ miles west of the Sidney section-house on G. N. R. R. Is 2½ miles from river; about one-half of a mile from, and on north side of, railroad. Is the highest land in vicinity.

Shepherd is on R. B., on "Shepherd Butte," 3½ miles from river, between Belt River and Highwood Creek, 2½ miles southwest of Shepherd's ranch, on Highwood Creek. △ is on highest part of butte, and close to west side.

Highwood is on R. B., on a grassy ridge about 5 miles from river, 3 miles north of Shepherd's ranch, on Highwood Creek; 1 mile north to an old house; a pond south of house.

Tunis is on L. B., three-eighths of a mile southeast of railroad station Tunis, about 7 miles west of Benton, Mont., on south end of a ridge which is the highest land in vicinity, about one-quarter of a mile south of G. N. R. R. track.

Cherry is on R. B., on end of bluff ridge ending in Cherry Coulée; is about 10 miles above Fort Benton, Mont., and 2 miles from river; about 3½ miles N. 35° W. from the "Nine-Mile House."

SECTION II.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, BETWEEN FORT BENTON AND TROVER POINT, MONTANA.

[Abbreviations: △=Secondary triangulation station. R. B.=right bank. L. B.=left bank. El.=elevation in feet.]

Benton is on the L. B., on the highest part of Benton Hill, 2 miles west from Fort Benton, and near the Helena road.

Teton is on the L. B., on a conspicuous hill, 1½ miles north of the Teton River and opposite the race course.

West Base is on the L. B., 2 miles northwest from Fort Benton, on a plateau between the Teton and Missouri rivers, near the edge of a gentle slope, above the deep bluffs of the Teton and about 100 feet east of a wagon road. El., 2,878.

East Base is on the L. B., 2 miles north from Fort Benton and 600 feet north of the railroad, on the highest ground in the vicinity. El., 2,893.

Hub is on the L. B., 1½ miles northeast from Fort Benton, on a prominent ridge; is marked by a gaspipe driven into the ground.

Shonkin is on the R. B., 2 miles below Fort Benton, on a dividing ridge between the Shonkin and Missouri rivers. The watershed around the station is toward the Shonkin.

Crocon is on the L. B., on the highest point below the sag, just below it, in the Crocondunez Ridge between the Teton and Missouri rivers.

Harvey is on the R. B., on a sharp point on the edge of the bluff, and about 2 miles from the mouth of the Shonkin.

Tele is on the L. B., on a knoll between the Teton and Missouri rivers, very near the telegraph line and near where the stage road to the eastward descends into the valley of the Teton.

Brulé is on the R. B., on the highest part of the bluff, opposite the site of old Fort Brulé.

Marias is on the L. B., about 1 mile northwest of the mouth of the Marias, on a high grassy peak.

Black Bluff is on the R. B., on the highest part of Black Bluff, 4 miles above the Marias.

Ridge is on the L. B., on a very high ridge about 3 miles from the river. The ri[dge] has a cut face and can be seen from a long distance.

Three Islands is on the R. B., on the highest ground in the vicinity of Three Isla[nd]s.

Recess is on the L. B., on a very prominent bluff about 1 mile back from the r[iver] at the head of a picturesque valley.

Mound is on the R. B., on a prominent mound about 1 mile from the river, fron[t] ... upper end of a high, cut bluff.

Coal Banks is on the L. B., on a plateau above the United States Military Land[ing], Coal Banks, and 200 feet south from a knoll, which has a stone pile on it.

Shanks is on the R. B., on a plateau near the edge of the bluff, 2 miles above Coal Banks and just below the sharp bend in the river.

Old is on the L. B., on a slight elevation, on an almost unbroken plain, about 1 mile northeast of Old Coal Banks.

Iron is on the R. B., on the highest point on the right bank of a creek, and about 1 mile from the river.

Sandy is on the L. B., on a trilobed hill, about 3 miles back from the mouth of Sandy Creek.

Burned is on the L. B., 2 miles southeast from Haystack Butte and 1 mile from the river. It is on the south edge of a pit-hole dug by the wind.

White Cliffs is on the R. B., on an elevation on a plateau, about 1½ miles from the river. This plateau is connected with another nearer the river by a narrow divide.

Wellman is on the R. B., 1½ miles from the river, on an elevation not far from the head of the left branch of the coulée in which Wellman Butte is situated.

Castle is on the L. B., one-half mile from the river, on the highest ground back from the castle-like rocks and dikes.

Kipps is on the R. B., on a plateau between two branches of a coulée, about 1½ miles from the river, just above Kipps Rapids.

Citadel is on the L. B., on the highest part of the middle hill of three prominent hills, about 1 mile from the river at Citadel Rock.

La Bargé is on the R. B., on a table-land near the edge of the bluff, about one-half mile from the river at a point one-half mile below Cathedral Rock.

Wall is on the R. B., about one mile from the river, and 3 miles below Hole-in-the-wall, on the highest ground in the vicinity.

Pinnacles is on the L. B., about 1½ miles back from Steamboat Rock, on the edge of a high plateau, only one knob in the vicinity being higher than the station.

Rondeau is on the R. B., 1½ miles back from the river at a point one-third of a mile below Pablos Rapids, on the highest ground in the vicinity.

Pablos is on the L. B., 1½ miles back from Pablos Rapids on the edge of a plateau, the highest ground within 1,000 feet.

Tip Top is on the L. B., on the highest ground yet occupied below Fort Benton, and is opposite the mouth of Arrow River.

Arrow is on the R. B., on the second peak on a plateau just below Arrow River, on the highest ground in the vicinity.

Plateau is on L. B., on the edge of a high plateau and about 4 miles below △ Tip Top.

Pines is on the R. B., three-fourths of a mile from the river, on a peak seen as a round knob from the river, on the highest ground in the vicinity.

Valley is on the L. B., at the northeast end of a ridge from the same plateau on which △ Plateau is located, and overlooks a large valley to the north and east.

Judith is on the R. B., 2 miles back from Judith, on a bluff of the east bank of Judith River.

Council is on the L. B., on a high ridge which separates the big valley opposite Judith from Birch Creek Valley, just back from some coulee heads, which are filled with pine trees.

Holmes is on the R. B., three-fourths of a mile from the river at a point one-half mile below Holmes Island, on the highest ground in the vicinity.

Iron City is on the L. B., on a divide between Birch Creek and the Missouri, one-half mile back from Iron City Island.

Gallatin is on the R. B., on a shelly mound about 1½ miles from the the river at a point one-half mile below Gallatin Rapids and Cary's ranch.

Bear is on the L. B., opposite Bear Rapids, on the highest ground in the vicinity.

Rapids is on the L. B., back from Dauphin Rapids about 1½ miles. Slightly higher ground lies between it and the river.

Dauphin is on the R. B., on a peak on a pine ridge one-half mile from the river and just below Dauphin Rapids.

Lone Pine is on the L. B., 2 miles from the river at a point one-half mile above Lone Pine Rapids. A natural rock mound marks the river end of the ridge, and the station is at the angle where the ridge bears to the right when going back from the river.

Chimney is on the R. B., on a very high peak, three-fourths of a mile from the river at a point one-half mile below the ruins of a stone chimney.

Windsor is on the L. B., 1 mile back from Magpie Rapids, on very high ground, just north of a very broken hillside.

Birds is on the R. B., on an elevation on a plateau about 2 miles from the river at Birds Rapids.

Sturgeon is on the L. B., three-fourths of a mile from the river at Sturgeon Islands, on the river edge of a plateau.

Spruce is on the R. B., 2 miles from the river from the mouth of a large coulee, on the edge of a plateau, the highest ground in the vicinity.

Snake Point is on the L. B., on a bluff point, three-fourths of a mile from the river from the islands just below Snake Point.

Cow Island is on the R. B., on a high point, three-fourths of a mile from the river just below Cow Island.

Landing is on the L. B., 1 mile from the river at the bend just below Cow Island.

Bend is on the R. B., on a high, conspicuous peak, 1 mile from river just below the big bend.

Crystal is on the R. B., on a very high elevation on a plateau, 1¾ miles from the river, one-third of a mile above Crescent Island, on the highest ground yet occupied.

Fortress is on the L. B., on the highest point of a high, conspicuous, sandstone ridge, about 1¼ miles from the river.

Quarter is on the R. B., about 1¼ miles from the river at a point one-half mile below Hammond Island, on the highest ground in the vicinity.

Grand Island is on the L. B., three-fourths of a mile from the river, on the highest ground, and commands a view of at least 5 miles of river.

Calf Island is on the R. B., 1 mile from the river at a point one-half mile below Two Calf Island.

Willow is on the L. B., 1¼ miles from the river at Two Calf Island, on a dividing ridge between several coulees.

Buffalo is on the L. B., on a knob about 1 mile from the river at a point 1 mile above Armel Creek, on the highest ground in the vicinity.

Armel is on the R. B., 1 mile from the river opposite Armel Island, on a prominent peak, the highest in the vicinity.

Brevier is on the R. B., on the second ridge, about 1¾ miles from the river at a point one mile below Harriet Island.

Harriet is on the L. B., about 1 mile back from the head of Harriet Island, on a very small, sharp mound.

Creek is on the L. B., on the highest point on the west side of Big Rocky Creek, 1½ miles from the river.

Rocky Point is on the R. B., on the summit of the second ridge, about 1 mile from the river, and one mile above Rocky Point.

Lopp is on the R. B., on a peak not in the main ridge, about 1 mile from the river at the sharp bend 2 miles by land below Rocky Point.

Autumn is on the L. B., one-half mile from the river, at a point 1 mile below Rocky Point, on a high, flat place, near the west edge of the plateau.

Carroll is on the R. B., one-half mile from the river, back from Carroll, on the highest ground in the vicinity.

Ryan is on the L. B., 3 miles from the head of Ryan Island, three-fourths of a mile from the river.

Ryan Island is on the R. B., on a high ridge, three-fourths of a mile from the river at the upper end of Ryan Island. A rock, 3 feet in diameter, is 16 feet south of the station.

Plain is on the L. B., three-fourths of a mile from the river at a point three-fourths of a mile below Ryan Island, on the northwest point of a plateau.

Sage is on the R. B., about 1¼ miles from the river, on the highest point in the vicinity. A very narrow ridge connects the station hill with the lower hills towards the river.

Kannuck is on the L. B., on the river end of the first ridge below Kannuck Valley, and is not on the highest ground. The top of the main ridge is back from the station, and there is slightly higher ground between it and the river.

Line is on the R. B., on an elevation on the ridge, 1¾ miles from the river, on the highest ground in the vicinity.

Across is on the R. B., on the highest point opposite Hawley Bend, on the highest ground in the vicinity.

Hawley is on the L. B., three-fourths of a mile north of Hawley Bend, on the highest ground in the vicinity.

Frost is on the L. B., on the divide between Hawley Valley and the Missouri River, 1 mile below the telegraph repair station.

Slide is on the R. B., on a prominent knob, 1¼ miles from the river, on the highest ground in the vicinity.

Pike is on the R. B., on a sharp ridge (200 feet in length), 1¼ miles from the riv

Lake is on the L. B., on the highest ground between the dry, alkali lake of Ha leys Basin and the Missouri, 1¼ miles from the Missouri.

Cut-off is on the L. B., three-fourths of a mile from the river where it strongly c the left bank, on the highest ground in the vicinity.

Above is on the L. B., one-third of a mile from the river, and 8 miles above mouth of the Mussel Shell River, on the highest peak in the vicinity.

Raid is on the R. B., on a ridge three-fourths of a mile from the river at a poin miles below △ Above.

Cow Boy is on the R. B., 1 mile from the river and 4 miles above the Mussel Sl

Mussell Shell is on the R. B., on a prominent bluff of the Mussel Shell, and 1 mile above its mouth.

Williams is on the L. B., opposite the mouth of Squaw Creek, and about 1 mile from Williams' ranch, on the highest ground in the vicinity.

Below is on the R. B., below the mouth of the Mussel Shell, about 8 miles, near the edge of a small, rocky plateau; three-fourths of a mile from the river.

Hornets is on the L. B., three-fourths of a mile back from the head of Hornets Nest Island, on the highest ground in the vicinity.

Nest is on the R. B., on a plateau, 2 miles from the river at a point just below Hornets Nest Island.

Wilson is on the L. B., 1¼ miles from the river, on an elevation on a prominent ridge.

Track is on the R. B., 1 mile from the river, on the projecting point of a plateau, on the highest point in the vicinity.

Elk is on the L. B., 1 mile from the river at a point 1 mile above Elk Island. It is on a projecting point of a plateau, but not on its highest part.

Horn is on the R. B., on the third prominent elevation, 1¼ miles from the river.

Forgey is on the L. B., on a low peak, between Fourchette Creek and the Missouri, about one-half mile from the river.

SECTION III.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, BETWEEN TROVER'S POINT AND FORT BUFORD.

[Abbreviations: △ =Secondary triangulation station. R. B.=Right bank. L. B.=Left bank.]

West Base is on L. B., about one-half of a mile below Elk Island, on a narrow bench between the bluff and river.

East Base is on L. B., 9,712 feet N. 73° E. from △ West Base, and is about 1 mile above where Trovers or Fourchette Creek comes out of the bluffs. It is 27 feet lower in elevation than △ West Base.

Trover's is on R. B., on a low, dark, naked ridge, and 1 mile from Rattle Snake Creek, and about same distance from Trover's Point.

Dog Town is on R. B., 4 miles below △ Trover, on a very prominent ridge, and about 2 miles from river.

Ball's Rock is on L. B., 6 miles below Fanchette Creek, on a high peak 1 mile from the river.

Rock Peak is on L. B., 1 mile below Timber Creek and 1½ miles back from river, on a nearly naked rock peak.

7 Black Feet is on R. B., about 2 miles from river at a point half way between 7 Black Feet Creek and Buffalo Shoals.

Gibson is on R. B., about 1 mile from the river from an island 2 miles above Gibson's ranch and about 4 miles above Round Butte. Round Butte bears N. 76° 20′ E. (true) from △.

3 Cañon is on L. B., opposite Gibson's ranch, and on third ridge from river. Bearing from △ to Round Butte is S. 37° 08′ E. (true), and distance about 5 miles.

Little Snow is on R. B., 3 miles below Round Butte and 1 mile from the river, on a rugged peak. Round Butte bears N. 81° 22′ W. (true) from △.

Grizzly is on L. B., about 1½ miles from river, and on low plateau between two coulees, and about 2 miles above two cone-shaped buttes. Round Butte bears S. 59° 08′ W. (true), and is about 6 miles distant.

Hell Creek is on R. B., three-fourths of a mile from river and 1 mile above Hell Creek, on a prominent peak.

Featherland is on R. B., about 2 miles above Featherland Island and 1½ miles from river.

Five Pines is on L. B., 1½ miles from river from a point just below Champaign Creek. Five pine trees mark the hill where △ is located.

Norris is on R. B., 1½ miles from river at Willow Island, which island is 1 mile below Flirt Creek. △ is about 1½ miles above Norris ranch.

Double Hill is on L. B., on high double hill and on northerly point. Line of hills runs northwest and southeast. South side of hill, where △ is built, is covered with pine.

Last Pine is on R. B., 1¾ miles from river, on bluff near pine trees.

Juniper is on L. B., on prairie, easy rise of 2 miles from river. Bare hill of nearly equal height west and across coulee. East side of hill where △ is, is covered with juniper.

Dry Fork is on R. B., on high knoll about 1 mile from river and about 1 mile below Dry Fork Creek. Tiger Butte bears N. 29° 44′ W. (true), and is about 14 miles from △. Lion Butte bears from △ N. 51° 05′ E. (true), and is about 5 miles distant.

Peck is on L. B., on divide between Missouri and Milk rivers, rolling prairie covered with grass, no trees in sight. River at nearest point is about S. 30° E. (mag.) from △. Tiger Butte bears N. 4° 12′ E. (true), and is about 9 miles distant.

Milk River is on R. B., three-fourths of a mile from river, on highest hill in vicinity. Mouth of Milk River lies N. 15° E. (mag.), and about 2 miles distant. Tiger Butte bears N. 56° 53′ W. (true), and is about 12 miles from Δ. Lion Butte bears S. 10° 30′ E. (true), and is about 3 miles from Δ.

Galpin is on L. B., on divide between Missouri and Milk rivers and on rolling prairie. Δ is about 3 miles from river. Lion Butte bears S. 41° 13′ E. (true), and is about 9 miles distant. Tiger Butte bears N. 29° 46′ W. (true), and is about 5 miles distant.

Nassau is on L. B., southwesterly from nearest point of Milk River, 1 mile distant, and about 2 miles above junction of the two rivers. Δ is on third ridge northerly from a sheep ranch. Kintyre railroad station bears S. 79° 04′ E. (true), and is 8 miles distant from Δ.

Bone Bluff is on R. B., 1 mile from river, and on the highest point of a long, curved ridge, which terminates in a low butte. Kintyre railroad station bears N. 12° 07′ E. (true), and is about 5¼ miles distant. Lennox railroad tank bears N. 51° 15′ E. (true), and is about 7 miles distant.

Kintyre is on L. B., about three-fourths of a mile S. 14° W. (mag.), from Kintyre railroad station. Δ is on rolling prairie, about one-half of a mile from railroad and 3 miles from Missouri River. Windmill at Lennox railroad station bears N. 88°, 33′ E. (true), and is about 5¼ miles distant.

Amelia Poe is on R. B., about 3 miles from deserted cabin, near river bank and opposite the wreck of the steamer *Amelia Poe*. Railroad tank at Lennox is N. 30° 50′ W. (true), and 7 miles distant. Railroad station Oswego bears N. 39° 49′ E. (true), and is about 7 miles distant.

Lennox is on L. B., on a bluff threeu-fourths of a mile east from a creek and 1¼ miles north from railroad. Higher bluff west of creek and northwest from Δ. Lennox railroad tank bears S. 63° 27′ W. (true), and is about 1 mile distant.

Santee is on L. B., and about 3¾ miles from river. Δ is on high knoll, behind which is rolling prairie. Oswego section-house chimney bears S. 86° 54 E. (true), and is about 2¼ miles distant.

Elk River is on R. B., on narrow plateau running from west to east. Large coulee is 300 feet south of Δ. Δ about 60 feet from top of bluff and about 1 mile from river. Oswego station-house chimney bears N. 57° 15′ W. (true), and is about 6¼ miles distant.

Oswego is on L. B., on highest ridge northeast from Oswego Siding, and about 600 feet north from the edge of bluff. Δ is near the head of Lone Tree Coulee, about 5 miles from the river. Oswego station-house chimney bears S. 44° 52′ W. (true), and is about 1¼ miles from Δ.

Hopkins is on R. B., on a knoll 1 mile from river from a point 3 miles above Wolf Point. The agency bears N. 00° 29′ E. (true), and is about 3 miles distant.

Wolf Point is on L. B., on westerly bluff of Wolf Creek, about one-fourth of a mile from creek and 4 miles from river. Oswego railroad station bears S. 67° 26′ W. (true), and is about 9 miles distant.

Macon is on L. B., on rolling prairie, about 1¼ miles back from edge of bluffs. Ground gradually rises back of Δ. Coulee 1 mile west of Δ; also, one 2 miles east. Windmill at Chelsea Siding bears S. 85° 40′ E. (true).

Spread Eagle is on R. B., on high plateau about 40 acres in area. This plateau extends southeast from Δ 1,000 feet, and the distance from Δ north to steep bluff is 90 feet.

Poplar is on L. B., about 3 miles from river and 1 mile west from Poplar River on an elongated hill and 1¼ mile back from southerly edge of bluff.

Redwater is on R. B., about 2¼ miles from River, on a ridge running east and west. Ridge terminates at Red Water Creek west of Δ. Windmill at Chelsea Siding bears N. 55° 04′ W. (true), and is 5 miles distant.

Deer Tail is on L. B., about 500 feet back from edge of bluff and nearly north from Deer Tail Indian town on river. A deep coulee lies about one-half of a mile west of Δ. Storehouse at Poplar bears S. 78° 22′ W. (true), and is about 6 miles distant.

Mortar Stone is on R. B., on high tableland about 2 miles from river at nearest point, and 2 miles above Mortar Stone Bluffs. Railroad tank bears N. 17° 31′ E (true), from Δ.

Box Elder is on L. B., below Box Elder Creek, on second high ridge back from river on prominent point with deep coulees on east and west sides of Δ. Δ is about miles from river.

Devils Elbow is on R. B., about 1 mile from river at Devils Elbow, on highest hill i the vicinity. The hill where Δ is built is connected with another hill almost a high by a narrow ridge south of Δ.

Big Muddy is on L. B., about 3¼ miles from mouth of the Big Muddy River. Δ on rolling prairie interspersed with deep coulees. Bluffs extend to within thre fourths of a mile from river, and the coal vein between Δ and river is on fire. Lanar railroad station bears S. 81° 05′ E. (true), and is about 9 miles distant.

Boulder is on R. B., on very high hill, which forms a part of the divide between a large creek and a large coulee. Railroad tank at Big Muddy bears S. 74° 30′ W. (mag.) from △. There is a large bowlder on top of hill 30 feet from △. Tank at Culbertson bears N. 8° 08′ E. (true), and is about 4½ miles distant.

Big Horn is on L. B., 2½ miles northwest from Big Horn Bluffs on river. Top of hill is about 200 feet long and 40 feet wide, running east and west nearly. Lanark railroad station bears N. 33° 27′ E. (true), about 3 miles distant.

St. Ange is on R. B., about 1½ miles from river. △ is situated on Fort Buford Military reservation near western line. Waterworks tank at Buford bears S. 76° 43′ E. (true), and is about 15 miles distant.

Lanark is on L. B., 4½ miles from river. △ is on high conical butte, north of which is a coulee running easterly to Little Muddy River. On south side of butte is a large overhanging rock making it conspicuous from the west.

Cut Off is on R. B., on oblong-shaped hill, which projects further toward the river than any other in the vicinity, and is about 1½ miles from the river. Railroad tank near Buford bears N. 85° 59′ E. (true), and is about 5½ miles distant from △.

SECTION IV.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, BETWEEN FORT BUFORD AND BISMARCK.

[Abbreviations: △=Secondary triangulation station. R. B.=Right bank. L. B.=Left bank. El.= Elevation in feet.]

Elevations depend upon published railroad data, the track at Buford railroad station being taken as 1,950 above sea level.

Ferry is on R. B., on a knoll 1¾ miles from the river and 1½ miles west from ferry and telegraph lines, and about 3 miles west from the mouth of the Yellowstone River. El., 2,181.

Montana is on L. B., on edge of high bluff northwest of railraad tank (west of Fort Buford, N. Dak.), and about 1½ miles from tank. El. not observed.

West Base is just east of road from Buford railroad station to the fort grounds and about one-fourth of a mile S. 36° W. from the railroad station. El., 1,932.37.

East Base is 2 miles N. 83° E. from West Base. A 12-foot timber station temporarily marks its location. El., 1,917.40.

Buford is on L. B., on high butte northeast from Fort Buford, N. Dak., called Mackenzies Butte, and about 4 miles from the fort. El. not observed.

Glass Bluff is on R. B., on the first cut bluff of the river, about 4 miles below Fort Buford on "Glass Bluffs." El., 2,096.

Trenton is on L. B., on high prominent bluff, coming almost to railroad track, about 3 miles west from Trenton section-house, which bears N. 15° E. from △. El. not observed.

Reservation is on R. B., on cut bluff about 3 miles west from eastern line of Fort Buford reservation. El., 2,128.

Jones Cut is on L. B., on rolling prairie, about one-half of a mile back of Jones Cut, which is 4 miles west from Williston, N. Dak. El. not observed.

Scott is on R. B., on high plateau, about 5 miles south of Williston and three-fourths of a mile from edge of bluffs. Station is on highest ground in the vicinity. El., 2,104.

Williston is on L. B., on low hill 2 miles northeast from Williston, N. Dak., and one-fourth of a mile east of Little Muddy Creek, at a sharp bend, this being the only bend of any size within sight of △. Railroad bridge over Little Muddy is two-thirds of a mile southwest. El. not observed.

Geries is on R. B., on outer edge of second cut bluff, about 9 miles below Williston. El., 2,163.

Ehorst is on L. B., two-thirds of a mile northeast from Ehorst's ranch. A trail leads from ranch up the coulee to northeast and passes near △, which is on a small knoll about 300 yards from edge of bluff. El. not observed.

Lagoon is on R. B., on edge of bluffs and near lake in old river bed. There are deep coulees both above and below △. El., 2,037.

ad Lands is on L. B., nearly at edge of bluff, on high ridge about 2½ miles back f n river. Ridge runs southeast, nearly, to cut bluff at river. About 1 mile to r theast are apparently higher bluffs. El., 2,259.

lum is on R. B., on middle one of three very high hills and about 2½ miles from e ,e of the cut bluff, which bluff is about 3 miles above Dan Harris ranch. To r ch △, go up deep ravine, and bear up to the left following a branch coulee. El., 2 7.

arris is on L. B., on high ground at head of coulee northeast from Harris ranch. S thwest from △ is an isolated bluff, and a little east from this bluff, but still s thwest from △, is a round-topped bluff with a small conical butte on its westerly e remity. El., 2,370.

Fire Hill is on R. B., on highest bluff in vicinity, and about 2 miles from the river at a point which is 2 miles above Garden Creek ranch. El., 2,320.

Nesson is on L. B., about 2 miles northeast from Frenchman's ranch and 4 miles northwest from Nesson post-office. △ is about 50 feet from wagon road from ranch to Nesson. El., 2,376.

Tobacco is on R. B., 1 mile from river, on highest part of plateau, and 2 miles above the head of Bear Island. El., 2,143

Grinnell is on L. B., on westerly of two high bluffs back from Grinnell's ranch. △ on highest part of bluff, and about $3\frac{1}{2}$ miles from river. At foot of bluff are several small isolated hills, and to the northwest and north are two larger and higher isolated hills. El., 2,264.

Strawberry is on L. B., on same line of bluffs as △ Grinnell and about 3 miles east. It is near edge of high bluff bank. About one-fourth of a mile west of △ is a small saddle, and just east is a deep coulee running into bluff. El., 2,322.

Lone Butte is on R. B., on highest part of prominent butte, 3 miles from river, and about 2 miles above the head of Strawberry Island. El., 2,444.

Elk Horn is on R. B., $1\frac{1}{4}$ miles from cut bluff of river and opposite the mouth of White Earth River. El., 2,156.

White Earth is on L. B., on high knoll (the nearest to river), about $4\frac{1}{2}$ miles from river and 3 miles from ford of White Earth River at a cut bank and near Hall's ranch and store. A trail leaves the road here, going over ridge to next valley, then up a spur on east side of valley. Ford of White Earth River bears about S. 30° W. from △. El., 2,311.

"Crow Flies High" is on R. B., on highest part of a plateau, about $1\frac{1}{4}$ miles from the cut bluff of the river and 4 miles above the camp of "Crow Flies High." El., 2,148.

Stony Hill is on L. B., on knoll about $1\frac{1}{4}$ miles back from river. Several piles of stone are near by station, and a deep coulee running to Knife River is about 1 mile east. About 2 miles back from △ are high bluffs. It is opposite village of Chief "Crow Flies High." El., 2,240.

Knife River is on L. B., one-half mile from river, just below first bend below Chief "Crow Flies High's" village. N. of E. from △ are two large rocks, 30 feet distant. One hundred yards north of △ is a coulee running to river. △ is 100 yards back from point of bluff. El., 2,146.

Oak Ridge is on R. B., on a point immediately above an oak grove, and is about midway between the prominent flat-topped butte and the river. El., 2,349.

Saddle Mountain is on R. B., at the end of down-river branch ridge of same plateau as Oak Ridge △ is on, and on highest part of steep wooded bluff. △ is about 1 mile from river. El., 2,304.

Indian Creek is on R. B., about 2 miles back from river on a small tableland, just beyond a very narrow place in ridge; about 3 miles below Indian Creek. El., 2,225.

Second Ridge is on L. B., on ridge very prominent, about 4 miles from nearest point of river. Rolling prairie all around. Coulee to east of △ runs toward the "Slide." El., 2,256.

Maneury is on R. B., on highest part of a long ridge running east and west, and is $1\frac{1}{4}$ miles from river and about 2 miles above a creek opposite old Fort Maneury. El., 2,309.

Independence is on R. B., on middle one of three cone-shaped buttes, and about 4 miles from river at Independence—an Indian village. El., 2,305.

Slide is on L. B., on high, steep bluff called the "Slide." Wagon road along the foot of bluff. △ is on edge of bluff about one-fourth of a mile from river. El., 2,058.

Little Missouri is on R. B., on low, rolling prairie, $1\frac{1}{2}$ miles from river and immediately above Little Missouri River. △ is about 400 feet north of bend in ridge road. El., 1,990.

Mission is on L. B., on a knoll 2 miles back from river and about 5 miles north of west from Indian Mission, and nearly opposite the mouth of Little Missouri River. Wagon road in coulee southwest from △, and an Indian ranch near river. △ is on highest knoll. El., 2,102.

Down is on R. B., on higher of two small plateaus, three-fourths of a mile from the river, and about 2 miles above where river leaves the bluffs. El., 2,097.

Scoria is on L. B., on highest point of bluff, at edge of rolling prairie. About e- fourth of a mile back from △ is a wagon road and telegraph line to Berthold; 00 yards southeast is a high and rugged isolated bluff. △ is about 11 miles west 1 m Berthold. El., 2,078.

Cairn is on R. B., and lies about S. 85° W. (true), 11.42 miles distant from rt Berthold. El., 2,215.

Berthold is on L. B., on first ridge north of and 4 miles from Old Fort Berthold A low, but prominent, conical butte is just east of a direct line from △ to the In ia school building. The agency bears E. of S. from △. El., 1,985.

Guide Meridian is on R. B., on open prairie, $1\frac{1}{2}$ miles from river, and 30 feet n h-

west from a dirt monument of the twelfth guide meridian. △ is about 2 miles southeast from Fort Berthold. El., 1,921.

Chippewa is on L. B., at Chippewa Point, about 5 miles below Berthold Agency. △ is on a spur running out from level prairie. Connected with this spur and south of △, by a deep saddle, is a bluff hill nearly as high. △ is about three-fourths of a mile from the river. El., 2,002.

Cook is on R. B., 1¼ miles south from Cook's ranch, on prominent hill near edge of bluffs. El., 1,978.

Emanuel is on R. B., about 1¼ miles above Emanuel Creek, on rolling prairie, and is about one-half mile northwest from a noticeable bowlder rock, and 1 mile from river. El., 1,958.

Stevenson is on L. B., northeast from Fort Stevenson and about 2¼ miles from the fort; is on a high ridge on west side near coulee. South of △ is a square bluff, and east of that some small red hills. El., 1,945.

Winslow is on R. B., on a rolling prairie, 1¾ miles from river and west from the Winslow ranch. △ is about 1,500 feet southeasterly from a mound marking the northeast corner of sec. 15, T. 147 N., R. 85 W. El., 2,046.

Robinson is on L. B., about 2 miles northwest of the town of Coal Harbor, N. Dak. △ is 100 feet from edge of bluff, and, between bluff and river, the coal vein is on fire. Bluff is very broken. El., 1,925.

Coal Harbor is on L. B., about 1 mile south of the town of Coal Harbor, on high knoll, on ground set apart for cemetery for above town. El., 1,984.

Hancock is on R. B., about three-fourths of a mile from the river on highest part of plateau, and one-half mile northeasterly from mound which marks the corner of townships 146 and 147 N., and ranges 84 and 85 W. El., 1,960.

Sundguist is on L. B., about 150 yards nearly due west from Sundguist's ranch, on knoll, and nearly opposite town of Stanton. El., 2,040.

Hoffman is on R. B., 2¾ miles southwesterly from court-house at Stanton, and is west of Big Knife River, on comparatively low ground. El. not observed.

Stanton is on R. B., 1¾ miles from river and 3 miles south of Stanton, and is below Big Knife River, on highest part of a prominent hill. El., 2,090.

Swenshern is on L. B., on knoll 400 yards east of Swenshern's ranch. El., 2,009.

Mandan Lake is on R. B., about 2¾ miles from river, on the highest hill in sec. 36, T. 144 N., R. 83 W. El., 1,900.

Washburn is on L. B., in SW. ¼ of sec. 7, T. 144 N., R. 81 W.; is 20 feet north of east-and-west line, between secs. 7 and 18, T. 144 N., R. 81 W., and 400 feet west of quarter-section corner on said line; is about 2¼ miles from the town of Washburn, McLean County, N. Dak. El., 1,908.

Ranch is on R. B., about 3 miles west of river at Painted Woods, on extreme south end of a ridge. △ overlooks a ranch to the south. El., 1,946.

Iverson is on L. B., on high bluff one-fourth of a mile southeast of Charles K. Iverson's ranch. This ranch is on the NW. ¼ of sec. 6, T. 142 N., R. 80 W. El., 2,123.

Square Butte is on R. B., on highest point of the south butte of the group called "The Square Buttes." El., 2,041.

Wogan is on L. B., on a high ridge east-southeast of Wogansport, and about 3 miles distant. △ is in SW. ¼ of sec. 21, T. 141 N., R. 80 W., and 150 yards north-northwest of quarter-section corner, between secs. 21 and 28. Telegraph line Washburn to Bismarck is one-half mile east of △. High buttes on R. B. in direction of Wogansport. El., 2,124.

Harmon is on R. B., three-fourths of a mile northerly from Harmon's ranch, which is situated at the edge of bluffs on Square Butte Creek. El., 1,942.

Sperry is on L. B., on round butte between two higher ridges, and 2 miles from the river. Main wagon road passes at foot of bluffs near river, but a road crosses ridge 100 yards south of △. Ranch in coulee two-thirds of a mile northwest of △, and also ranch 1 mile southeast. El., 1,979.

Mandan is on R. B., 3 miles northwesterly from Mandan and near wagon road running from there. It is the most prominent hill in the vicinity, which hill is a spur running out towards a flat-topped hill 300 feet towards the river. Hill can be seen rom any direction for many miles. There is a rolling plateau towards the river. l., 1,999.

Marysville is on L. B., on mound-shaped hill, about 4 miles northwest from Bismarck, . Dak. On higher ground one-fourth of a mile east is the Washburn-Bismarck ad. El., 1,956.

ECTION V.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, FROM BISMARCK, NORTH DAKOTA, TO PIERRE, SOUTH DAKOTA.

[Abbreviations: △ =Secondary triangulation station. R. B.=Right bank. L. B.=Left bank.]

Bismarck is on L. B., on northeast bend of a plateau about 2 miles northeast from smarck, N. Dak., and about 1¼ miles west of north from the penitentiary, 2,500

feet northeast of Catholic cemetery, on the highest ground in vicinity. △ is 60 feet back from edge of bluff looking towards Burnt Creek and 60 feet northwest from a granite bowlder, 10 by 12 feet, which is partially buried.

Lincoln is on R. B., on the highest point of the bluff, just north of Fort Lincoln, and 1,300 feet from the mouth of Big Hart River.

North Base is on L. B., in the bottom, 580 feet south of the N. P. R. R. at a point 1,101 feet west from the first trestle west of Bismarck depot.

South Base is on L. B., 16,650 feet S. 18° E. from △ North Base, on a somewhat prominent knoll in bottom.

Little Hart is on R. B., three-fourths of a mile from river, about one-half mile west from Riverside ranch, on the east end of the most prominent hill in the vicinity.

Kayhall is on L. B., on crest of a mound-shaped hill, about 8 miles southeast of Bismarck, 3¼ miles from river, on land belonging to Mr. Kayhall, and 750 feet from his house.

Riverside is on R. B., 2¼ miles from river, on a high plateau, near north edge of hill. A wagon road one-half mile west of △.

Glencoe is on L. B., on a small, rocky tableland on a range of very high hills, 2¼ miles southeast of Glencoe post-office, and about 3 miles from the river. There is higher land three-fourths mile nearly south of △.

Fort Rice is on R. B., about 6 miles southwest of the site of old Fort Rice. As seen from first bluff at mouth of Fort Rice Creek, it is a square-topped hill and highest land in sight. The △ is on west end of an east-and-west ridge.

McIntyre is on L. B., on a high bluff, 3 miles northeast from the mouth of Long Lake Creek, and one-half mile south of the creek. There is higher land one-fourth mile southeast. The △ is nearly east from the site of old Fort Rice.

Cannon Ball is on R. B., about 3 miles from the mouth of, and on R. B. of, the Cannon Ball River. △ is about 1 mile back from the "Twin Buttes," on the highest land in the vicinity.

Gayton is on L. B., on a long, narrow, detached ridge, about 2 miles northeast from Gayton's Landing, and 4 miles southeast from mouth of Cannon Ball River. The △ is 20 feet from edge of bluff, and 200 feet southwest from highest part of ridge. There is higher land three-fourths mile north.

Givens is on R. B., on first ridge of hills, about 1¼ miles up Cannon Ball trail from Government schoolhouse, Mrs. Van Solen, teacher; is a long, level-topped hill, with a mound 3 feet high and 100 feet wide at base. There is a round, grassy-topped hill north.

Beaver Creek is on L. B., 2¼ miles from river. It is in the SW. ¼, sec. 32, T. 133 N., R. 78 W., and is 64 feet east and 817 feet north from southwest corner of said section. The south line of section 32 is the seventh "Standard Parallel."

Van Solen is on R. B., on a small, mound-shaped hill in a gentle rolling prairie 2¼ miles back from river, one-fourth of a mile south of a ravine running to river, three-fourths of a mile east from telegraph line to Fort Yates. The △ is not on a prominent hill.

Little Beaver is on L. B., on east end of a well-defined ridge, about 2 miles from river, and three-fourths of a mile south from Little Beaver Creek, 8 miles by river above Winona, N. Dak.

Battle Creek is on R. B., on a detached hill, one-half mile south from Battle Creek, and one-half mile from river, 20 feet from edge of bluff.

Cathead is on L. B., on a high butte in center of a prairie, about 4 miles from Winona and 3¾ miles from river. The △ is in NE. corner, sec. 3, T. 130 N., R. 79 W.

Fort Yates is on R. B., on a flat-topped hill, one-half mile northwest from Fort Yates, about 500 feet south from the highest part of the hill.

Winona is on L. B., 4 miles southeast from the town of Winona, N. Dak., and 2¼ miles from the river at nearest point. The △ is on crest of the highest land in the vicinity.

Fire Heart is on R. B., on Fire Heart Butte, about 2 miles from river and 6¼ miles below Fort Yates. It is on the highest of a cluster of hills in that vicinity, and the nearest to river.

McRay is on L. B., 2 miles from river, about 400 feet east from the southwest end of a very high ridge. There is a small tip 400 feet west that is higher than △ The △ is probably in SE. ¼ sec. 1, T. 129 N., R. 79 W.

Martin is on R. B., 2½ miles from river, on east side of a spur which forms a divide between two creeks. The △ is about 4 miles northwest from "St. Benedict" Indian mission.

Doerschlag is on L. B., 2¼ miles from river, one-half mile east from Louis Doerschlag's house. It is on second bench of land above the river bottom. The △ is one-half mile southwest from a very high, prominent butte.

St. Benedict is on R. B., on extreme northeast point of a very high ridge, 5¼ miles southwest from St. Benedict Mission. A flat stone found on hill was used to mark △ instead of the regulation stone.

La Grace is on L. B., on west end of a very high ridge, 2¼ miles north from the town of La Grace. The △ is on a small, rocky mound, 72 feet from edge of bluff.

Box Elder is on R. B., on a large rolling plateau, 2 miles from river and near edge of bluff; on divide next south from Box Elder Creek.

Kirkland is on L. B., on a very high ridge which is bluff to west, and 45 feet south from a well-traveled road. There is higher land near edge of bluff one-half mile northwest; also one-half mile southeast. The △ is in SW. ¼ sec. 33, T. 127 N., R. 78 W.

Blume is on R. B., on a definite hill, 1 mile southwest from a group of lower hills on the low plateau opposite Campbell post-office and 2½ miles from river.

Campbell is on L. B., about 4 miles from river at Campbell post-office. The △ is on Johnny Johnson's claim and 200 feet northwest from his sod house. The house is on line between △ and quarter corner, on south side of sec. 35, T. 126 N., R. 78 W. The △ is 2,035 feet above corner, and is in NE. ¼ SW. ¼ sec. 35.

Ashley is on R. B., on south end of a ridge, just back of the head of Ashley Island.

Roth is on L. B., on a definite mound-shaped hill on plateau, about 1¼ miles southwest from John Roth's sod house. The △ is (from best information at hand) near the center of sec. 36, T. 125 N., R. 79 W.

Grand River is on R. B., on a slight elevation of general plateau, first high part of plateau, about 1 mile below the mouth of Grand River.

Aske is on L. B., on crest of a round-topped hill, about 5 miles east from the mouth of Grand River and 500 feet east from a surveyed road. The △ is probably in the SE. ¼ of NW. ¼ sec. 15, T. 124 N., R. 79 W.

Blue Blanket is on R. B., on a flat-topped hill, opposite head of Blue Blanket Island and 1½ miles back. Is on highest land in vicinity.

Fox Island is on L. B., on a projecting point of a range of hills, about 2¼ miles north from Fox Island. The hill is the most prominent as seen from river, but there is higher land one-half mile east. The △ is about three-fourths of a mile east from Blue Blanket Creek, marked by the usual stone and a "U. S. B. M." pipe.

Curlew is on R. B., on second plateau, about 1 mile from river, south of the mouth of a draw running into river a little above middle of Fox Island.

Bennett is on L. B., 3½ miles east from river, on land of D. C. Bennett, and 61 feet southwest from southeast corner of his house, 948 feet northwest from quarter section corner and south side of sec. 11, T. 122 N., R. 78 W.

Le Beau is on L. B., on hill standing off by itself, 1 mile from the river. The △ is on spur towards Le Beau post-office.

McKinley is on L. B., on a smooth plateau, at head of Rush Creek and 4 miles from river at mouth of Rush Creek; 1¼ miles northwest from Albert Roseno's house, which is near the head of a branch of Swan Creek, 150 feet from east edge of bluff, and 1,555 feet northeast from the quarter section corner on the south side of sec. 36, T. 122 N., R. 78 W.

St. Stephen is on R. B., on a slight hill north of a wooded valley and 4 miles below St. Stephen Mission and 2 miles from river. There is higher land 300 feet northwest, also one-half mile north. △ is opposite mouth of a small creek on L. B.

Scranton is on L. B., on a small, mound-shaped hill, 1¼ miles back from river and 2¼ miles southeast from town of Scranton, S. Dak. The △ is 1,284 feet southwest from the southwest corner of sec. 36, T. 121 N., R. 78 W., which is on the fifth "Standard Parallel." The △ is probably in sec. 2, T. 120 N., R. 78 W.

Charger is on R. B., on a point in bend of river opposite Forest City, S. Dak., and 2 miles west of Chief Charger's camp.

Bunker Hill is on R. B., on a very high and prominent hill known as Bunker Hill, 2¾ miles from river at J. G. Webb's house. The △ is on the highest land north of the gap in the range of hills through which runs a wagon road; is 786 feet southeast from the quarter section corner between secs. 21 and 22, T. 119 N., R. 78 W.

Traversy is on R. B., on a small mound standing alone, 2½ miles back from river, at a point 3 miles above Pascal Island, and is the highest land in vicinity.

Forest City is on L. B., on a slight rise of ground on bluff ridge, south of the first ravine south of the new town of Forest City, S. Dak., and is near the head of said ravine.

Pascal is on R. B., on the highest part of a smooth, grassy ridge, running nearly north and south, and 2 miles west from foot of Pascal Island. The ridge is three-fourths mile long, slopes gently to the west, but is steeper at the east; higher land south and southwest.

Artichoke is on L. B., on a sharp knob of a hill of the Artichoke Buttes, and 1½ miles from river. The △ is on the high butte to left of road up divide.

Plum Island is on R. B., on a small knoll on broken plateau, 6 miles from river at Plum Island, and north of west end of big bend near Cheyenne River. Higher land 1 mile northwest; a wagon road 150 feet from △.

Fairbank is on L. B., on the north end of a very prominent range of hills, 4 miles nearly east of the town of Fairbank, S. Dak. The △ is 873 feet west and 30 feet south from NE. corner of sec. 14, T. 115 N., R. 80 W.

Fort Bennett is on R. B., on a prominent hill 3¼ miles west from Fort Bennett, S. Dak. The hill is about the most prominent point looking west up valley from the fort.

Sully is on L. B., on a high and rocky point on the northernmost of the Sully Buttes, about 7 miles northeast from Fort Bennett, S. Dak. There is a quarter section corner 525 feet west of △. Section line runs 30 feet south of △.

Fielder is on R. B., on a long ridge parallel with river and near lower end of ridge, 2 miles back from river, opposite Fort Sully.

Ingham is on L. B., on a high plateau, 2 miles from river. A white house surrounded by grove of trees is one-half mile west. The △ is in SW. ¼ of sec. 20 T. 112 N., R. 80 W.

Ferry is on R. B., on a small ridge, about one-half mile east from Willow Creek and 3 miles south from ferry landing at Oähe, S. Dak. The △ is 15 feet east from edge of bluff and 375 feet west from wagon road from Pierre to Fort Bennett.

Stony Hill is on L. B., on a small, stony hill, three-fourths mile from river and 6 miles above Pierre, S. Dak. It is 25 feet from bluff and 900 feet west from wagon road.

Brown Hill is on R. B., on east end of a large plateau, and on a quite prominent hill. Highest land in the vicinity.

Snake Butte is on L. B., on spur nearest river, of a long ridge, about 4 miles above Pierre, and 200 feet west of a wagon road to Pierre. The hill is the most prominent in that vicinity.

Fort is on R. B., about 2½ miles west from river, and 2½ miles north from Bad River, on a narrow ridge, first one from river. Higher land back of △.

Pierre is on L. B., on a very prominent, sharp hill, 1,000 feet east from the water works reservoir, and 1¼ miles northeast from court-house at Pierre, S. Dak. The △ is near southeast end of ridge.

Bad River is on R. B., on east end of a grassy ridge 300 feet long, 1¼ miles below Fort Pierre, one-half mile back and to the west of the mouth of Bad River.

Cemetery is on L. B., on ridge running down to cemetery and about 2 miles northeast from the "Wells House," in East Pierre, and one-fourth mile back from cemetery.

SECTION VI.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, FROM PIERRE TO RUNNING WATER, SOUTH DAKOTA.

[Abbreviations: △ = Secondary triangulation station. R. B. = right bank. L. B. = left bank.]

West Base is on L. B., in bottom, half way between first low line of bluffs and river, and is in southeast corner SE. ¼ sec. 4, T. 110 N., R. 79 W. It is directly towards the river from the "Wells House," in Pierre, and near the west end of a large pasture field next the river.

East Base is on L. B., in the bottom, 12,000 feet S. 75° 57′ E. from △ West Base, 800 feet west from farmhouse in bottom, and 1,603 feet from the Chicago and Northwestern Railway.

Plateau is on R. B., on spur of plateau pointing towards Pierre, 4¼ miles below Fort Pierre and three-fourths mile back from river. There is higher land one-fourth of a mile southeast.

Farm Island is on R. B., 1½ miles from river, on highest point of ridge, and is nearly opposite the foot of Farm Island.

Barth is on L. B., on a projecting prominent point opposite middle of Farm Island, one-half mile northeast from Barth's house, which is near the river bank. The △ is 50 feet from edge of bluff, and is marked by a cross cut on the top of a granite boulder, 1¼ feet below surface.

Perry is on L. B., on a very prominent point connected to main plateau by a "hog-back," three-fourths mile nearly east of Mrs. Perry's house, 1¼ miles from river, 25 feet from south edge of bluff.

Narselles is on R. B., on upstream end of a ridge 350 feet long and parallel with river; highest land in immediate vicinity. △ is not on highest part of ridge. A wagon road from Fort Pierre to old Fort George is 350 feet north from △.

Rousseau is on L. B., near the brow of a hill, 1 mile from river. A small grave with picket fence is 200 feet east from △; a small graveyard with large black cross, on next spur east. △ is 595 feet from SE. corner SE. ¼ sec. 16, T. 110 N., R. 77 W.

Fort George is on R. B., on a very high and prominent "hog-back" ridge, near head of Fort George Creek, one-half mile south from creek and 3 miles from its mouth. A large pile of boulders 30 feet north of △. There are two higher ridges, which resemble one on which △ is located, 2 miles farther back.

Jacques is on L. B., on first high point back from river, which is the highest of several just in front of higher plateau, 1 mile back from river, opposite mouth of Fort George Creek, one-fourth mile east from Judy Jacques' house, and one-fourth of a mile north from C. C. Barry's sod house.

Chapelle Creek is on L. B., on brow of first high bluff; country back of △ is high plateau 1¼ miles east of Jones' ranch, which is also De Gray post-office, and 1¼ miles from river.

Cedar River is on R. B., on east end of the middle lobe of a long, narrow ridge, 3¼ miles from river, at a point 1¼ miles below foot of Dorin Island No. 1.

Reynolds is on L. B., on a small, flat table-land 250 feet in diameter, on highest land in vicinity, 1 mile east from Reynolds Creek (Joe Creek), and 4 miles north of the mouth; 3 miles west from St. John's ranch. The △ is south of the wire fence across the bend.

Neck is on R. B., in the neck of the Big Bend, near center of a grassy ridge running southeast and northwest, and at the highest point. The △ is one-fourth mile from river, and on last hill toward the bend.

Big Bend is on L. B., on northwest end of a ridge 200 feet long running northwest and southeast, and 1 mile from river. Southeast end covered with rock around △. High hills 1 mile back.

Burnt Ridge is on R. B., on a very high and prominent range of grassy hills, 5 miles south from the neck of the Big Bend. There is higher land one-half mile southeast directly on line towards Medicine Butte. The △ is 1,023 feet northwest from the southeast corner of T. 107 N., R. 74 W.

Fort Thompson is on L. B., about 3¾ miles north from Fort Thompson (Crow Creek Agency) and 1¼ miles east from Soldier Creek, three-eighths mile west from a small creek running into Soldier Creek, 40 feet east of road running north from the fort.

Badger Creek is on R. B., on a round knoll 100 feet in diameter, 3 miles back from mouth of Badger Creek. Highest land in vicinity.

Wolf Creek is on L. B., 1 mile west from Wolf Creek (Elm Creek), and 4 miles north from mouth of creek, on a low hill, but first one of any size back from river.

Bluff is on L. B., 20 feet from edge of bluff, 2 miles east from the site of old Fort Lookout, 3 miles southeast from Fort Hale, 1 mile back from the river. Highest land in vicinity.

Fort Lookout is on R. B., on a flat-topped hill, 1¾ miles from river, near a corn field, 75 feet from a road running to Brulé Agency.

Prichard is on L. B., on a round-topped hill, one-half mile back from river, three-fourths mile northeast from George Prichard's residence, 2,686 feet northeast from N. W. corner Sec. 1, T. 104 N., R. 71 W. The △ is 200 feet east from the edge of bluff, and about 30 feet south from east and west half-section line through section 36.

Brulé is on R. B., about 1,000 feet from end of a long, narrow plateau running toward river; 2¼ miles south from Brulé Agency.

Chamberlain is on L. B., on high plateau land 1¼ miles south from Chamberlain, S. Dak., 866½ feet northeast from quarter-section corner between Secs. 22 and 27, T. 104 N., R. 71 W. The △ is on rolling prairie, about half way between Mr. Wellman's residence and that of Major Kellum. There is higher land 400 feet southwest.

Indian is on R. B., on a small mound on a crooked, broken ridge, 3¼ miles from river at a point 1¼ miles below mouth of White River. There is a high point on top of same ridge 1 mile south of △.

Willrodt is on L. B., on a very prominent round-topped hill, three-eighths of a mile west from Mr. Willrodt's house and 1 mile from river. △ is on land of D. W. Spaulding.

Rosebud is on R. B., on a small mound on very high ridge, 30 feet from edge of abrupt bluff on south. The hill is 5 miles from river. A prominent, sharp butte is one-half mile nearer river.

Bijou is on L. B., on a very high and prominent butte, three-fourths mile back from river. The △ is on highest part of butte. There is a larger and higher butte nearly 1 mile south.

Durex is on R. B., on south side of a small plateau, 100 feet from edge of bluff, 1 mile west from head of Durex Island and about the same distance from mouth of Rosebud Creek, one-eighth mile north of road from Rosebud Landing to Rosebud Agency. There is a small butte one-fourth mile north, 50 feet higher than △.

Brickkiln is on R. B., 2 miles back from river, 1¼ miles from Brickkiln Hill, and [illegible] miles southeast from Dry Creek. The △ is on highest land in vicinity. A wagon road running up Dry Creek passes 800 feet north.

Heaton is on L. B., on a small ridge 600 feet long and 75 feet wide at summit, 2¼ miles back from river; highest land in the vicinity. Near house of W. H. and C. C. Heaton.

Cologne is on R. B., on a prominent mound 200 feet in diameter and 25 feet high, 2¼ miles from river. The mound is at the head of ravine and near edge of a large plateau. Mr. Cologne lives 5 miles north of △.

Boland is on L. B., on a round-topped hill on rolling prairie, about 4 miles from river and 3 miles northwest from Castalia, S. Dak., three-fourths mile nearly north from John Boland's house and 1 mile northeast from a frame schoolhouse. The △ is 2,367 feet northwest from the SE. corner of Sec. 17, T. 99 N., R. 69 W.

Hamilton is on R. B., on a spur of a large, rolling plateau running out toward river, one-half mile back from foot of Hamilton Island. Highest land within a mile.

Kyle is on L. B., on a very prominent ridge at head of Cedar Creek; hill is the highest in vicinity. There is a round mound at south end of ridge 250 feet from △, which probably is as high as △. The △ is in the S. ½, SE. ¼, Sec. 15, T. 98 N., R. 68 W.

Mule Head is on R. B., the hill being the highest in vicinity, and 1¼ miles west from Mule Head Point.

Wheeler is on L. B., 4½ miles northeast from Wheeler, S. Dak., and five-eighths mile east from Campbell Creek, on a knob of a projecting spur of plateau. There is higher land 1¼ miles northwest across creek, and a prominent cone-shaped hill one-half mile south, which is nearly as high as △.

Whetstone is on R. B., on north end of a very high and prominent peak or ridge, 2¼ miles from river; highest point in vicinity; covered with rock.

Chicot is on R. B., back 1¼ miles from foot of Chicot Island, 75 feet north from foot of plateau, and 25 feet west from the bluff edge. Between river and △ there is a butte about as high as △.

Leonard is on L. B., on a very high ridge, back 4 miles from river at head of Chicot Island, 3 miles from Bartholdi post-office. The △ is on highest point in a group of hills, one-half mile south from the "Armour Road."

White Swan is on L. B., about 4 miles east from White Swan, S. Dak.; on land of Little Brave (Indian), and about 600 feet from his house, 450 feet north from wagon road to Yankton Agency.

Harrison is on R. B., on Nine-mile Hill; a good camping place, there being a good spring 300 feet away. A road from Fort Randall goes over top of hill. The △ is 8 miles nearly south of Fort Randall.

Bruce is on R. B., on a mound-shaped hill, on dividing ridge between the Missouri River and Ponca Creek, 600 feet from edge of bluff, 550 feet north from wagon road from Niobrara to Fort Randall, and 2 miles southwest from Yankton Indian Agency.

Conger is on L. B., 4 miles from river, and 6 miles east from Yankton Indian Agency, on a very high ridge, a spur of which runs out nearly west and 300 feet west of △; is higher than △. An Indian house on low ground is in sight 1,000 feet north.

Ponca is on R. B., on a very high and prominent sharp-topped sandstone butte, 2 miles south of Ponca Creek, and 5 miles from river. Butte can be seen for miles from any direction. The △ is marked by a cross in a "pick-up" sandstone and regulation pipe. Highest mass of rock on butte is 15 feet northwest from △.

Chouteau is on L. B., 1¼ mile back from river at mouth of Chouteau Creek, and one-half mile west from said creek. The △ is on flat tableland 175 feet east from wagon road. Higher land one-fourth mile north.

Ward is on R. B., on a slight rise on a ridge running east and west, 15 feet north of a land survey mark—a mound with four small pits—one-fourth of a mile north from main traveled road from Niobrara and 25 feet east of a branch of main road, 5 miles west of Niobrara, Nebr.

Arneson is on L. B., 2 miles back from river, on a high ridge. The △ is 300 feet from north end of ridge. There is a sharp-pointed hill, three-fourths of a mile south, as high or higher than △. A wagon road within 40 feet of △ runs northeast towards a small white school-house. The △ is 594 feet northeast from the SW. corner Sec. 3, T. 92 N., R. 61 W., and one-fourth of a mile east of Arneson's house.

Niobrara is on R. B., on a very sharp round-topped knob at west end of ridge which turns north 200 feet east of △, runs north 300 feet, and ends in a knob similar to one at west end. The △ is about 2 miles from river opposite Running Water. Higher land 1 mile south of △.

Covell is on L. B., on a small mound on a rolling prairie on land belonging to Mr. Covell, one-fourth of a mile south from his house, 2 miles back from river, and 3 miles southwest from Springfield, S. Dak.

SECTION VII.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS, BETWEEN RUNNING WATER, SOUTH DAKOTA, AND BLAIR, NEBRASKA.

[Abbreviations: △=Secondary triangulation station. R. B.=Right bank. L. B.=Left bank.]

Kelly is on L. B., on a rather flat hill and slightly on its southern slope. A wagon road runs around the △ to house of Hugh Kelly. △ is 1,200 feet southeast from said house.

Lost Creek is on R. B., and 1 mile back from a point 1¼ miles below mouth of Lost Creek. The land is the highest in immediate vicinity.

North Base is on L. B., in the bottom, 4½ miles northeast from Running Water, S. Dak. The △ is in NE. ¼, SW. ¼, Sec. 10, T. 92 N., R. 60 W., and on land owned by

Mr. Barnum, of Niobrara, Nebr. The west line of this section crosses base line 2,758 feet from △. Magnetic bearing of base line is N. 24° 30′ E.

South Base is on L. B., 300 feet north of the river, one-half of a mile nearly east from the railroad depot at Running Water. The △ is on a slight rise.

Santee is on R. B., on a very sharp ridge, about 5½ miles southeast from Santee Indian Agency, and 3 miles from river. The land 150 feet south from △ is higher, and some distance north a sharp spur runs out and slopes very abruptly into valley. A road from Santee Agency runs 200 feet west of △.

Springfield is on L. B., about 4½ miles northeast from Springfield, S. Dak., and 2½ miles from river on a slight rise in rolling prairie. The △ is 66½ feet west and 2,403 feet north from quarter-section corner. △ is in NE. ¼, SW. ¼, sec. 8, T. 93 N., R. 59 W.

Herrick is on R. B., on a flat-topped triangular hill, 3½ miles from river. Two hundred and fifty feet west from △ is a sharp peak, but not so high as △. The △ is one-fourth of a mile east of Devils Nest Creek and is 3,444 feet southwest from NE. corner of Sec. 34, T. 33 N., R. 3 W.

Bon Homme is on L. B., about 4 miles east from the village of Bon Homme, S. Dak., 1½ miles back from river on a narrow, sharp ridge—the highest land in the vicinity. The land 1½ miles west is as high as △. The △ is 2½ miles northeast of the Mennonite village, and from the best information at hand is in the NW. ¼ Sec. 14, T. 93 N., R. 58 W.

Pit is on R. B., on a mound-shaped hill 4 miles from river, and on the highest land in vicinity. A large rolling prairie surrounds the hill. The △ is on north end of hill; a gravel pit a few feet north of △; one-half of a mile southeast to Louis Metzler's. The △ is supposed to be in NW. ¼, Sec. 35, T. 33 N., R. 2 W.

Lakeport is on L. B., on a mound hill on a narrow ridge, 10 feet south from wagon road, and 50 feet north from cultivated ground, 3½ miles from river, and is near the middle of NW. ¼ Sec. 11, T. 93 N., R. 57 W.

Schmidt is on R. B., about 5½ miles southeast from the ferry landing opposite Yankton, S. Dak. The △ is in a cultivated field 1,397 feet northwest from the SE. corner Sec. 29, T. 32 N., R. 1 W., and is on the land of Balthser Schmidt, and one-fourth of a mile east of his house. The △ is built on first high land east of Schmidt's house. One and a half miles east from △ the land is higher.

Welby is on L. B., about 6 miles southeast from Yankton, S. Dak., 1,000 feet northeast from Welby schoolhouse, and one-fourth of a mile northeast from Welby's house. The hill is a little, flat mound in a large rolling prairie—the highest land in vicinity, however. The △ is 415 feet east, and 1,706 feet south from NW. corner, sec. 26, T. 94 N., R. 55 W.

Bow Creek is on R. B., 20 feet from edge of a perpendicular bluff, 100 feet from river and 1½ miles up river from Wiseman's ranch, and same distance below mouth of Bow Creek. The bluff extends back some distance forming a plateau; deep ravine 800 feet up river slightly timbered. The △ is said to be in sec. 7, T. 32 N., R. 3 E.

Spirit Mound is on L. B., on a very prominent butte, 7 miles north from Vermillion, S. Dak. The hill is known as Spirit Mound.

Johnson is on L. B., about 10 miles from river, 1,000 feet east from Brulé Creek, and one-fourth of a mile northeast from John Erickson's house; on a ridge between Brulé Creek and a deep ravine; higher ground a mile or so distant north and east. The △ is said to be in NW. ¼, sec. 1, T. 92 N., R. 50 W.

Ryan is on R. B., on a very prominent "hog-back" ridge, one-half of a mile from river, three-fourths of a mile above Thomas J. Ryan's ranch, and on land of Fred. Calvert. The △ is in NE. ¼, NE. ¼, sec. 32, T. 32 N., R. 5 E., and 13 feet north from a pit 4 by 4 by 6 feet deep.

Westfield is on L. B., on a sharp and very prominent point, 5 miles nearly due east from Elk Point, S. Dak., 6 miles south from Westfield, Iowa, and 1½ miles east of the Big Sioux River. The △ is on highest point of a broken ridge, and is said to be near center of sec. 24, T. 91 N., R. 48 W.

Ionia is on R. B., near edge of the bluff, about 3 miles below the site of the old town of Ionia. The △ is in NE. corner, NW. ¼, NE. ¼, sec. 19, T. 31 N., R. 6 E., on land owned by George Matteson. The △ is on a prominent, sharp-pointed bluff, one-fourth of a mile southwest from Mr. Baltzley's house.

Triloba is on R. B., on the second knob above the point of bluff between Missouri River and Iowa Creek, and 2 miles east from the town of Ponca, Nebr. The △ is on a low bluff, and 10 feet from perpendicular face to northeast. There is a sharper and higher point 450 feet northwest, and a very much higher and larger bluff one-half of a mile northwest.

Hall is on L. B., about 9 miles north from Sioux City, Iowa, and 3 miles east from Jefferson, S. Dak.; is on a slight mound on a winding ridge, one-fourth of a mile northeast from the Big Sioux River. George Hall lives one-half of a mile south of △.

Round Cap is on R. B., on the highest knob just below Kinsler's bend and 1 mile from river.

Emerson is on L. B., 1½ miles north from mouth of Big Sioux, and one-fourth of a

mile east, on a sharp oval-shaped mound on broken ridge, 10 feet from edge of abrupt bluff. A church stands on a hill one-half of a mile northeast. The Sioux City Highland Railway Company's roundhouse stands under the bluff 500 feet distant.

Prospect Hill is on L. B., on Prospect Hill, Sioux City, one-half of a mile west from the depot and one-eighth of a mile from the river bank; is marked by a vertical railroad iron.

Sargent is on the L. B., one-half of a mile northeast from the town of Sargent Bluffs, Iowa, on a small knoll in a narrow ridge, the highest point in the vicinity; is in the SE. ¼ of the NE. ¼ of sec. 30, T. 88 N., R. 47 W.

Baird is on the R. B., on a prominent point, one-half of a mile southeast of Colonel Baird's house and 3 miles from the river; is 374 feet west of the NE. corner of sec. 3, T. 27 N., R. 8 E.

Hedges is on the L. B., on a high point, 1½ miles northeast of Hedge's ranch and 9 miles east of Salix, Iowa; is in the SW. ¼ of the NW. ¼ of sec. 30, T. 87 N., R. 45 W.

Winnebago is on the R. B., one-half of a mile south from the north line of Winnebago Indian Reservation, and 1½ miles southwest from the house of W. P. Allen, which is on the SW. corner of sec. 25, T. 27 N., R. 9 E.

Grant is on the L. B., on a prominent point, 10 miles northeast from Whiting, Iowa; is in the NE. ¼ of sec. 18, T. 85 N., R. 44 W.

Blackbird is on the R. B., on Blackbird Hill, on the river bank about 5 miles northwest from Decatur, Nebr.; is in the SW. ¼ of sec. 4, T. 24 N., R. 10 E.

Kennebec is on the L. B., on brow of the bluff, just back of the white frame house owned by N. W. Hathaway; is about seven-eighths of a mile northwest of Arcola, Iowa; is in the SE. ¼ of sec. 20, T. 84 N., R. 44 W.

Sandig is on the R. B., on a bare knob, 4½ miles south of Decatur, Nebr., and five-eighths of a mile west of Sandig's house; is in the NW. ¼ of sec. 25, T. 23 N., R. 10 E.

Mormon is on the L. B., on a high knob, 1½ miles east of Little Sioux, Iowa; is in the SE. ¼ of NE. ¼ of sec. 20, T. 81 N., R. 44 W.

Tekamah is on the R. B., one-fourth of a mile southwest from Tekamah, Nebr., and 1,000 feet west from the C., St. P., M. & O. R. R. depot; is in the SW. ¼ of the SW. ¼ of sec. 19, T. 21 N., R. 11 E.

Taylor is on the L. B., 4½ miles southeast from Mondamin railroad station, and 950 feet southeast from NW. corner of sec. 2, T. 79 N., R. 44 W.

Herman is on the R. B., 2 miles south of Herman, Nebr., and one-fourth of a mile east of D. O'Halin's house; is in the NE. ¼ of the SW. ¼ of sec. 8, T. 19 N., R. 11 E.

SECTION VIII.—DESCRIPTION OF PERMANENT STATION-MARKS, SECONDARY TRIANGULATION STATIONS BETWEEN BLAIR BASE AND LEAVENWORTH.

[Abbreviations: △ =Secondary triangulation station. R. B.=Right bank. L. B.=Left bank.]

East Base is on R. B., near the river, one-fourth of a mile southeast from W. Tyson's house; is near the center of the SW. ¼ of sec. 18, T. 19 N., R. 12 E.

West Base is near the center of the SE. ¼ of sec. 15, T. 19 N., R. 11 E., 2½ miles west from △ East Base.

Bench is on R. B., on a low ridge, three-fourths of a mile north of Blair, Nebr., and 2 miles west of the S. C. & P. R. R. bridge, in the SW. ¼ of sec. 1, T. 18 N., R. 11 E.

Blair is on the R. B., on a hill, 2 miles south by east of Blair, Nebr., and 2¾ miles southwest of the S. C. & P. R. R. bridge; is one-fourth of a mile southwest from the Blair-Omaha wagon road.

Loveland is on the L. B., on a high, wooded ridge, one-fourth of a mile northeast from Loveland railroad station; is in the NW. ¼ of the NE. ¼ of sec. 3, T. 77 N., R. 44 W.

Douglas is on the R. B., 2½ miles from the river and one-fourth of a mile northwest from D. Shipley's house; is in the NW. ¼ of the NE. ¼ of sec. 5, T. 16 N., R. 13 E.; is 200 feet south of county line.

Crescent is on the L. B., on a high peak, one-half of a mile southeast from Crescent railroad station; is in the NE. ¼ of the SW. ¼ of sec. 26, T. 76 N., R. 44 W.

Council is on L. B., on the outer ridge above Council Bluffs, and one-eighth of a mile above the G. A. R. monument.

Omaha is near the southwest corner of Lake and Thirty-second streets, Omaha; is 100 feet northwest of the Ætna brickyards.

Bluffs is on a narrow ridge, on line of Twentieth street, Council Bluffs; is on the north line of the SW. ¼ of the NE. ¼ of sec. 1, T. 74 N., R. 44 W.

Bellevue is on R. B., 1½ miles northwest from Bellevue, Nebr., on land owned by Dr. Chaffee. A timber station temporarily marks the hill.

Henton is on the L. B., on a high knob, one-half of a mile northeast from Henton railroad station; is on the south line of sec. 20, one-third of a mile from SW. corner, T. 73 N., R. 43 W.

Platte is on R. B., on an Indian mound, 250 feet south of the "Park House," 2¼ miles northwest of Plattsmouth, Nebr.; is in the NW. ¼ of the SE. ¼ of sec. 1, T. 12 N., R. 13 E.

Quarry is on the L. B., on a prominent hill, 4 miles north from Bartlett; is east of the frame house of the Haney Estate; is in the NW. ¼ of the NW. ¼ of sec. 21, T. 71 N., R. 43 W.

Calumet is on the R. B., 3 miles southwest from Rock Bluff, Nebr., and 1,000 feet northeast from the house of G. J. Oldham; is in the SW. ¼ of the NW. ¼ of sec. 19, T. 11 N., R. 14 E.

Thurman is on the L. B., on a prominent ridge, 1¼ miles north of Thurman post-office, and east of Allen's house; is in the NE. ¼ of the SW. ¼ of sec. 23, T. 70 N., R. 43 W.

Jones is on R. B., 1 mile west from the rock quarry at Jones Point; is in the NE. ¼ of the SW. ¼ of sec. 20, T. 10 N., R. 14 E. The center of the section is on line with △ Thurman, 1,161 feet distant.

Pugh is on the L. B., on a large knob, 3¼ miles south of Thurman post-office; is east of the house of J. M. Mann; is in the SE. ¼ of the SW. ¼ of sec. 13, T. 69 N., R. 43 W.

Otoe is on R. B., 1½ miles below the bridge at Nebraska City and 1¼ miles above Otoe City; is in the SW ¼ of the SW. ¼ of sec. 14, T. 8 N., R. 14 E.

McCracken is on L. B., on a most prominent ridge, 6 miles north by west of Hamburg, Iowa; is south of McCracken's house, in the SE. ¼ of sec. 30, T. 68 N., R. 42 W.

City is on R. B., on a cultivated hill, 1¼ miles above above Otoe City; is in the NW. ¼ of sec. 1, T. 7 N., R. 14 W., on land of G. N. Brinker.

Hamburg is on L. B., on a small bare knob of a cross ridge, 4 miles south-southeast of Hamburg, Iowa; is in the SE. ¼ of the SW. ¼ of sec. 2, T. 66 N., R. 42 W.

Peru is on the R. B., on a high point in a ridge, 1½ miles below Peru, Nebr.; is on the line between sections 22 and 23, and 2½ miles from the south line of T. 6 N., R. 15 E.

Phelps is on the L. B., 3 miles northeast of Phelps, Mo., on a cultivated hill; is in the SE. ¼ of sec. 18, T. 65 N., R. 41 W.

Brownville is on the R. B., on a narrow ridge, three-fourths of a mile north of Brownville, Nebr.; is on section line between sections 7 and 18, and is one-third of a mile from the west line of T. 5 N., R. 16 E.

Langdon is on L. B., on a bare knob, 2 miles south of Union City, Mo.; is in the NW. ¼ of sec. 9, T. 64 N., R. 41 W.

St. Deroin is on the R. B., on a narrow ridge, three-fourths of a mile above St. Deroin, Nebr.; is in the SW. ¼ of sec. 25, T. 4 N., R. 16 E.

Nishne is on the L. B., on a wooded ridge 2 miles east of Nishne, Mo., and 1 mile from the edge of the bluffs. Is in sec. 1, T. 63 N., R. 41 W.

Devoir is on the R. B., on a high ridge, 1 mile from the river. Is in the NW. ¼ of the NW. ¼ of sec. 9, T. 3 N., R. 17 E.

Craig is on the L. B., in a wooded pasture field, on a hill 1½ miles north by west from Craig, Mo., just east of the road. Is in the NE. corner of sec. 2, T. 62 N., R. 40 W.

Arago is on R. B., on a timbered hill, 1½ miles below Arago, Nebr. It is in the NW. ¼ of sec. 18, T. 2 N., R. 18 E., on land belonging to Coon Smith.

Nemaha is on the R. B., on a flat-topped mound, on a long ridge near the river, at the mouth of the Big Nemaha.

Napier is on the L. B., on a narrow, bare ridge, three-fourths of a mile east-southeast of Napier railroad station, and just east of the graveyard on the hillside.

Forest City is on L. B., on a broad, cultivated hill, three-fourths of a mile southeast of Forest City, Mo. Is 600 feet south of D. W. Carder's house.

White Cloud is on R. B., on a high hill, 1¼ miles below White Cloud, Kans. Is in the south part of sec. 15, T. 1 S., R. 19 E.

Lookout is on R. B., on Lookout Mountain, three-fourths of a mile northeast of Eagle Spring Hotel. Is in the NE. ¼ of the SW. ¼ of sec. 10, T. 2 S., R. 20 E.

Payne is on L. B., on a wooded ridge, 2 miles southeast of Curzon Switch, Mo. Is northwest of Robert Moore's house, which is owned by J. Payne. Is in the NE. ¼ of the NE. ¼ of Sec. 23, T. 59 N., R. 38 W.

Meers is on the R. B., on a bare hill 4¼ miles west of Charleston City, Kans. Is in the SW. ¼ of SE. ¼ of sec. 20, T. 2 S., R. 21 E.

Nodaway is on L. B., on a wooded ridge, 2 miles above Nodaway River. Is in the S ¼ of sec. 23, T. 59 N., R. 37 W.

Fox is on the R. B., on a ridge one-fourth of a mile southwest of J. R. Fox's house. Is in the NE. ¼ of the SW. ¼ of sec. 30, T. 2 S., R. 22 E.

Amazonia is on L. B., on a bare hill one-half of a mile northwest of Amazonia, Mo.; is in the SW. ¼ of the NW. ¼ of sec. 35, T. 59 N., R. 36 W.

St. Joe is on L. B., on a cultivated bluff, about one-fourth of a mile north of St. Joseph waterworks reservoir; is in the SW. ¼ of the SE. ¼ of sec. 30, T. 58 N., R. 3[illegible] W.

Kings Knob is on L. B., on a very prominent knob known as Kings Knob, 2 miles south of the railroad bridge at St. Joseph.

Wathena is on R. B., on a high point one-half of a mile southwest of Wathena, Kans.; is in the NW. ¼ of the NE. ¼ of sec. 33, T. 3 S., R. 22 E.

Anderson is on the R. B., on an Indian mound, on the highest point, one-quarter of a mile east of Haye's house; is in the SW. ¼ of sec. 17, T. 4 S., R. 22 E.

Kenmoor is on L. B., on a narrow wooded ridge, one-half of a mile east of Kenmoor railroad station; is in the SW. ¼ of the SW. ¼ of sec. 22, T. 56 N., R. 36 W.

Geary is on the R. B., on a mound on a wooded ridge, 2 miles below Geary City, Kans.; is in the NE. ¼ of sec. 3, T. 5 S., R. 21 E.

Halls is on L. B., on a wooded ridge 1¼ miles southwest from Halls, Mo.; is 75 feet south of graveyard on the bluff; is in the NW. ¼ of sec. 6, T. 55 N., R. 36 W.

Atchison is on R. B., on a wooded ridge 2¼ miles north of Atchison, Kans., on land owned by Charles Brown; is in the SE. ¼ of the SE. ¼ of sec. 19, T. 5 S., R. 21 E.

Gordon is on L. B., on a broad pasture field, 4 miles east of Winthrop, Mo.; is in the SE. ¼ of the SE. ¼ of sec. 22, T. 55 N., R. 37 W.

Snyder is on R. B., in a cultivated field 3 miles below Atchison, on land owned by E. Snyder; is in the SW. ¼ of sec. 17, T. 6 S., R. 21 E.

Reese is on L. B., on land owned by Martin Reese; is 42 feet southeast of the southeast corner of the dwelling house; is in the SE. ¼ of sec. 12, T. 54 N., R. 37 W.

Oak Mills is on R. B., on a high point one-half of a mile above Oak Mills, Kans.; is 1,000 feet northwest of the house of George Waddle; is in the NE. ¼ of the SW. ¼ of sec. 12, T. 7 S., R. 21 E.

Iatan is on L. B., on a high wooded spur from a knob 1¼ miles south of Iatan, Mo.; is in the SE. ¼ of sec. 29, T. 54 N., R. 36 W.

Kickapoo is on R. B., on the first high hill above Kickapoo railroad station; is in the northwest corner of an apple orchard; is 15 feet east of the west line of sec. 29, T. 7 S., R. 22 E.

APPENDIX A 5.

REPORT OF MR. CHAS. F. POTTER, DIVISION ENGINEER, ON SHORE-LINE SURVEYS.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
Omaha, Nebr., June 5, 1891.

LIEUTENANT: I have the honor to submit the following report of shore-line surveys under my charge during the year ending June 30, 1891:

I was instructed, by letter dated September 19, 1890, to make preparations for making a survey of the Missouri River from Sioux City, Iowa, to Jones Point, Nebr., and on the following day was directed to proceed with the work.

As there were no boats in the vicinity of Sioux City for sale or hire that could be converted into quarter boats, it was found necessary to construct cabins on one 64 by 16 foot barge and on one 30 by 11 foot flat at Omaha, for the accommodation of the party.

On October 1 the survey party was organized and the quarter-boats were supplied with provisions, tools, and material necessary for the work.

October 2 the boats were taken in tow by the steamer *Capitola Butt* and started for Sioux City.

Owing to low water on the crossings navigation was found difficult, and in consequence the tow did not reach Sioux City until the evening of October 6.

The towboat started for Omaha the next morning, arriving there two days later.

The survey was commenced October 7. A locating party was first started out to establish tertiary triangulation stations, and after the first few days was usually from 10 to 15 miles in advance of the main party.

The stations consisted of a gas-pipe hub, 3 feet by 1½ inches, carrying a pine flagpole 1¼ by 1¼ inches by 10 feet, with a system of red, white, and green flags, arranged so that the numbers from 1 to 9, inclusive, could be easily distinguished.

The main party consisted of the assistant in charge and four transitmen, together with the necessary rodmen, boatmen, cooks, watchmen, etc., and was subdivided in the following manner:

A triangulation party, which was occupied in measuring the angles of the angles, and in connecting the tertiary with the second triangulation systen stadia party on each bank of the river, employed in locating shore and bar li and a third stadia party, which located the permanent bench-marks and some tion corners.

Aside from the chief, the party was made up almost wholly of men inexperien in river surveys, and in consequence progress was necessarily slow for the week; however, before the end of the first month a channel distance of from 5 miles per day was covered.

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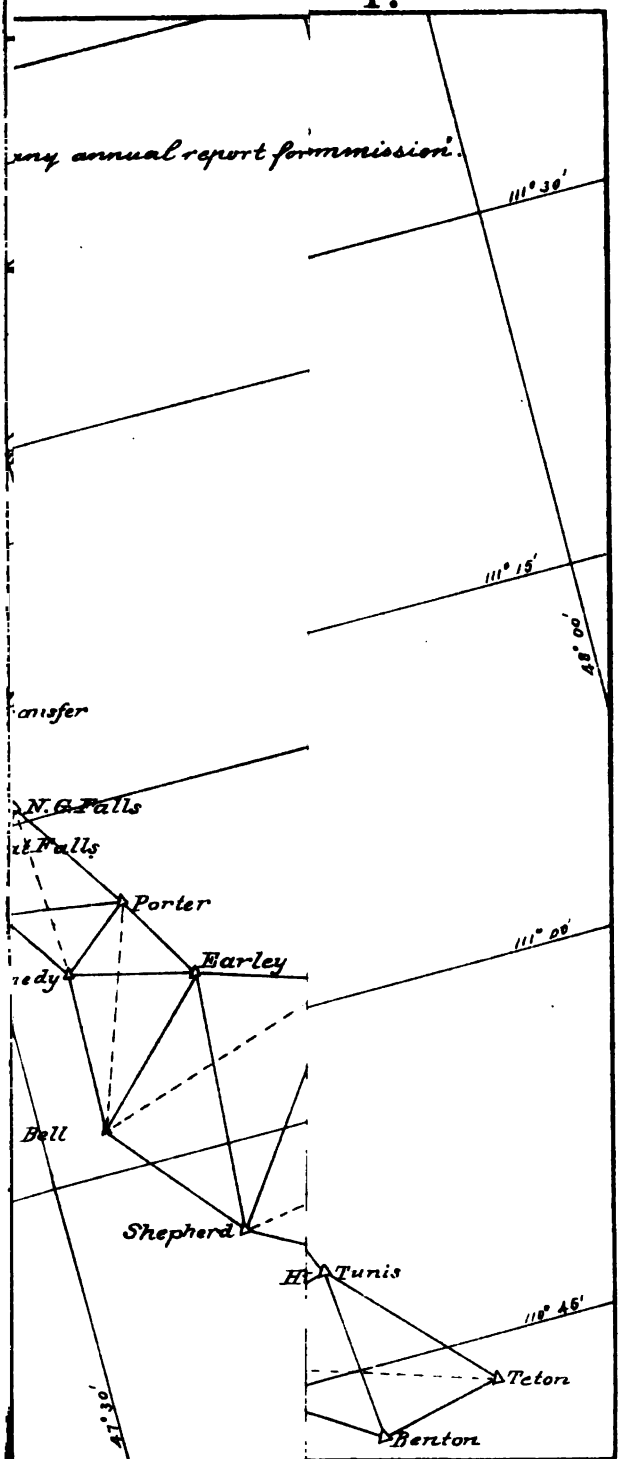
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No survey of the river from Florence to Omaha and between Bellevue and Plattsmouth was made; the notes of surveys made in 1889 and 1890 were used in making the map.

From Florence to Jones Point the location of the bench-marks was omitted for the time, owing to the approaching cold weather and the desirability of completing the main survey before the ice should interfere with the movements of the quarter-boats.

The survey was practically completed on November 28. The boats and skiffs were then floated down to Nebraska City and pulled on the United States ways for the winter, and the party was disbanded.

Two assistants were retained, and were employed during the month of December in calculating the tertiary triangulation.

About January 1 work of platting the secondary triangulation from notes sent from the St. Louis office was commenced, and was followed by the platting of the tertiary triangulation and stadia notes.

The platting of the charts covering the Omaha division was finished in pencil, and they were forwarded to St. Louis on the following dates: Chart XXIII, February 5; Chart XXIV, February 14; Chart XXII, February 20 (sent to Division Engineer S. W. Fox); Chart XXV, February 28; Chart XXVI, March 11; Chart XXVII, March 25.

The permanent bench-marks from Florence to Jones' Point, which were omitted from the survey in November, were located and platted during the month of April, and a tracing of the same sent to the St. Louis office on May 15.

The work of tabulating the coördinates of the tertiary triangulation was completed May 20 and, as this ended all work connected with the shore-line survey under my charge, the force was transferred to other duties.

SPECIAL SURVEY.

I was instructed, by letter dated October 13, to make a survey of the Omaha Harbor.

The necessary soundings were made 1st day of December, and the shore-lines surveyed on January 2. A map was made from the notes obtained, and a tracing of the same sent to the St. Louis office on March 16.

I wish to acknowledge the valuable services rendered by Assistant Ed. Jones as chief of the survey party.

Financial statement showing cost of shore-line survey.

Cost of labor in field	$3,164.62	
Cost of labor in office	1,008.33	
Cost of supplies (flags, hubs, etc.)	475.50	
Cost of subsistence	714.58	
		$5,363.03
Towing quarter boats to Sioux City, Iowa:		
Charter	160.00	
Fuel	152.50	
Labor	171.00	
		483.50
Total expense of shore-line survey		5,846.53

The above expense was divided between three allotments, as follows:

Survey allotment	2,799.70
Omaha allotment	375.38
Sioux City allotment	2,671.45
Total	5,846.53

I am, very respectfully, your obedient servant,

CHAS. F. POTTER,
Division Engineer.

First Lieut. J. C. SANFORD,
Corps of Engineers, U. S. A.,
Secretary Missouri River Commission.

APPENDIX A 6.

REPORT OF MR. S. WATERS FOX, DIVISION ENGINEER, ON SHORE-LINE SURVEYS.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
St. Joseph, Mo., June 19, 1891.

SIR: I have the honor to submit herewith a report of the shore-line survey of the Missouri River conducted under my charge last fall between Jones Point, Iowa, and Beverly Junction, Mo.

With a view to doing the work as rapidly as possible, with reasonable accuracy and at a minimum cost, the following general scheme of field work was arranged, viz:

A constant orient for each and all of the transits in use was to be carried, whether running a continuous line or doing fragmentary meander work, with numerous reciprocal readings for checking orientation and stadia—this orient to be the magnetic meridian as indicated by some particular one of the transits. Should all the instruments get out of orient by cumulative or accidental errors, they were to be reset as at first—this to done when near a secondary triangulation station, so that both new and old orient could be readily azimuthed from observations at said station. In case any one instrument should get out of orient, it was to be set from an adjacent instrument, and the fact so stated in the notes. The shore-line parties were to keep close watch for transit points on the P. B. M. lines, for fences, land corners, etc., locating them when possible. Points that it was desired to locate, and that could not be seen from shore-line transit points, were to be located by a meander line run with an instrument that was not carrying a continuous line. The accessible secondary triangulation stations were not to be occupied until after the shore-line parties had passed them, so that angles might be taken to as many transit points as possible. Those reaches of the river that had been surveyed a short time previous to this survey (aggregating 30 miles of river) were to be skipped after making proper ties to them.

A party was organized, and the major portion of it reported for duty at Nebraska City, Nebr., September 29, 1890, to Assistant Joseph C. Meredith, who was placed in direct charge in the field.

The United States quarter-boat *Pappoose* was repaired and equipped for the use of the party.

Active work in the field began October 1, 1890, though it was not until October 20 that the following full personnel of the party was in service, viz: One assistant engineer, in charge; two shore-line parties, each consisting of one transit-man, two stadia-men; one island-bar party, consisting of one transit-man, one stadia-man; one side or detached party, consisting of one transit-man, one stadia-man; the crew of the quarter boat *Pappoose*, consisting of one pilot, two oarsmen, one cook, one waiter, making, all told, sixteen men.

NOTE.—The pilot and oarsmen, when not engaged in dropping the quarter-boat, were employed as skiffmen and axmen for the shore line and island-bar parties.

November 1, Assistant Meredith was relieved from further duty on the survey, that he might return to his station at Nebraska City, Nebr., and Mr. Frank V. Potter was placed in charge of the party.

In accordance with instructions dated Kansas City, Mo., November 24, work in the field was stopped at a point opposite Beverly Junction, Mo., and the party ordered to proceed on board the *Pappoose* to Kansas City, where they were to report to Division Engineer Yonge for further instructions and to turn over the property to him.

The party arrived at Kansas City November 27, and the transfer of property was effected the same day. Assistant F. V. Potter reported to me at St. Joseph November 29 for duty in the office.

The preliminary work incident to making charts of the survey was begun at once, Assistant Potter giving all his time, and Mr. Widen, the draftsman at this office, as much of his time as could be spared from his regular duties.

Lack of space for drafting tables did much to hinder the progress of this part of the work; but difficulties of platting, to some extent inherent in the system of field work and more largely due to the inexperience of the transit men, combined to make the work tedious, costly, and unsatisfactory.

Six charts in all, from Chart XVI to Chart XXI, both inclusive, and a portion of Chart XXII, were worked up in pencil and forwarded to you, the last one leaving this office March 24, 1891.

Length of river surveyed:		
Gross	miles..	201
Net	do...	171
Stadia distance run	do...	328.5

Number of:

Stations occupied		1,259
Angles read		14,586
Island bars located		319
Secondary triangulation stations located		54
P. B. M's located		43
Cost of field work:		
Labor	$1,803.51	
Materials, supplies, transportation	423.10	
		$2,226.61
Cost of office work:		
Labor	671.78	
Material, sundries	11.00	
		682.78
Total cost of survey		2,909.39
Cost per mile:		
Field work		$13.02
Office work		3.99
Total average cost per mile for 171 miles of river surveyed		17.01

Very respectfully, your obedient servant,

S. WATERS FOX,
Division Engineer.

First Lieut. JAMES C. SANFORD,
Corps of Engineers, U. S. A.,
Secretary Missouri River Commission.

APPENDIX A 7.

REPORT OF MR. SAMUEL H. YONGE, DIVISION ENGINEER, ON SHORE-LINE SURVEYS.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
Kansas City, Mo., June 20, 1891.

SIR: I have the honor to submit my report on shore-line surveys of the Missouri River, carried on under your direction, during the fiscal year ending June 30, 1891.

In compliance with instructions received from you under date of September 20, 1890, an estimate of cost and also of time required for the proposed survey was submitted under date of September 21, 1890.

The necessary preparations having been made, by putting two quarter-boats in serviceable condition, organizing survey parties, etc., work was begun October 17, 1890.

The survey extended from Weston Island, below Weston, Mo., to the mouth of the river, a distance of about 427 miles.

The total length of river surveyed amounted to 336 miles, not including 91 miles which had been covered by detached surveys made previously, as follows, viz:

From the foot of Sharp's Bend to Wellington, Mo., a distance of 56 miles, by Assistant Grady, in May and June, 1890; from the head of Millers Island to Miami, Mo., a distance of 5 miles, by Assistant Grady, in the summer of 1890; from Miami, Mo., to the head of Buckhorn Bend, a distance of about 11 miles, by Assistant Crawford, in July, 1890; from Saline City, Mo., to Arrow Rock, Mo., a distance of 7 miles, by Assistant Crawford, in September and October, 1889; from P. B. M. $^{4}_{1}{}^{1}$ to a point about three-fourths mile below Boonville Bridge, or a distance of 3 miles, and from Etlah to Dundee, a distance of 9 miles, by Assistant Grady, in the summer of 1890.

Four parties of about 20 men each, quartered on small flatboats, were employed in making the survey.

The first party, in charge of Assistant A. H. Weber, left Kansas City October 6, and began work at Marion Mo., about 224 miles below Kansas City, on October 17.

It finished its work on December 13, 1890, in Spring-House Bend, 135 miles below Marion, having surveyed 126 miles of river, 9 miles of the distance having been covered by a previous survey, as stated above.

It immediately proceeded to St. Louis, Mo., where it was disbanded, the quarter boat being taken to Bushburg, Mo.

The second party, under Assistant R. A. Crawford, left Kansas City, October 1, reached Wellington, Mo., 61 miles below Kansas City, on October 17, and began its work, which was completed on reaching Searcys Landing, 139 miles below Wellington, on December 19.

This survey covered 112 miles of river, 26 miles of the distance between the two points named having been covered by previous surveys.

Upon the completion of the work the quarterboat was dropped to Jefferson City, from whence it was taken to Bushburg, Mo.

Assistant Crawford's party then proceeded to Weston, Mo., reaching there on December 22, and carried the survey from the foot of Weston Island to the mouth of the Kansas River, a distance of 34 miles, reaching the latter point January 13, 1891.

The third and fourth parties were sent out because it was thought that on account of the near approach of winter it would be impossible for the first two parties to complete the survey to the mouth of the river before the latter would be closed by ice.

The third party, in charge of Assistant R. F. Grady, left Kansas City November 29, reached its destination, Searcy, about 200 miles below Kansas City, December 8, and completed the work to Marion, Mo., on December 19, having surveyed 24 miles of river.

The party then proceeded to Jefferson City, where it was disbanded, and the quarter boat taken to the winter harbor at Bushburg, Mo.

The fourth party, in charge of Assistant I. D. McKown, began work at the head of Spring-House Bend December 1, and completed the survey to the mouth of the river, a distance of 32 miles, December 27.

The party was then disbanded, and the quarter boat taken to Bushburg.

Incidental to this work, a survey of the river was made, extending from the mouth of the Kansas River to the foot of Sharp's Bend, below Kansas City, Mo., a distance of about 8 miles.

The shore-line survey consisted in meandering the high-water banks of the river, taking the topography for about 1,000 feet back from each bank, and locating sandbars, islands, and steamboat channels.

In surveying the shore lines, and in other similar work, the stadia rod was used, the stadia transit lines being connected with a tertiary system of triangulation, the stations of which were located about three-quarters of a mile apart, along the river banks.

The tertiary triangulation work was carried on in advance of the shore-line work, and was connected by triangulation, usually at intervals of 4 or 5 miles, with the stations of the secondary triangulation previously established on the bluffs of the river valley by Assistant O. B. Wheeler, wherever these stations were within easy reach.

The coördinates of the stadia transit lines and the tertiary triangulation stations were, as a rule, computed as the work progressed, and corrected as to azimuth and position with reference to the plane coördinates of the secondary system.

As the field parties were composed principally of young men of little or no experience in survey work and unskilled in the methods employed, much credit is due the assistants in charge of parties for the satisfactory results attained.

The following is a résumé of the work done: Number of tertiary triangulation stations erected and occupied, 869; number of secondary triangulation stations connected with tertiary system, 71; permanent bench-marks connected with, 77; number of miles of transit stadia lines run in locating river banks, islands, etc., 918.

The total cost of the field work of the survey amounted to $12,044.36, about $2,200 of which was expended in getting the parties to the points selected for commencing work, making the net cost of the survey $9,800, or about $29.17 per mile of river surveyed.

During the winter months the field notes were platted on fifteen charts, drawn to a scale of 1,000 feet to 1 inch, all of which work was done at Kansas City, with the exception of Chart I, and parts of Charts II, IV, VII, and XI.

The platting was completed March 18, 1891, and the charts forwarded to your office.

The total cost of the drafting done at Kansas City amounted to $1,414.

Very respectfully, your obedient servant,

SAML. H. YONGE,
Division Engineer.

First Lieut. J. C. SANFORD,
Corps of Engineers, U. S. A.,
Secretary Missouri River Commission.

APPENDIX A 8.

ANNUAL REPORT OF MR. D. W. WELLMAN, ASSISTANT ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
St. Louis, Mo., June 30, 1891.

SIR: I have the honor to submit herewith the following report on the permanent bench-mark work for the year ending June 30, 1891.

This work extended from Sioux City, Iowa, to Fort Leavenworth, Kans. Actual work in the field was begun July 3, 1890, and ended November 4. Ten days were spent in organizing parties, procuring supplies, and making some needed repairs to the quarter boats.

Two separate parties were organized for the work, one to locate the lines and plant the bench-marks, the other to ascertain their elevation by carrying lines of levels from bench-marks established along the river in 1880 and 1881.

The parties were transported on two small quarter boats which had been used the previous season by parties engaged on the secondary triangulation above Sioux City. The boats were propelled by side-sweeps, and steered by an oar at the stern. In calm weather they were easily handled; but in even a moderate wind they became unmanageable. At such times they would go ashore somewhere, and we would have to wait until the wind subsided.

The bench-marks were set on lines running across the valley, the lines being usually about 5 miles apart by the river distances.

Previous to starting, diagrams showing approximately the proposed location of the lines had been made on a set of lithograph maps of the river and the scheme thus shown was followed throughout the work as nearly as was found practicable. Usually three bench marks were set on a line. In some instances, however, owing to the nature of the ground, only two were placed on a line, and in two cases, only one. In one case an entire line (No. 136) was left out for similar reasons, and also because the lines at this place had been projected unusually close together; but to avoid confusion in the notes, the numberings as laid down on the preliminary diagram were retained, so that in designating the bench-marks only the number of a line will be skipped.

The bench-marks established were of the type adopted and used heretofore by the Commission. They have been fully described in previous reports.

In selecting sites for the bench-marks, the endeavor was always to get them into some yard or field near a dwelling, with the owner's consent. He thus became a sort of watchman and a protection to them in some degree. When this could not be done, they were placed, as far as practicable, by the side of some public road or fenced field.

A transit stadia line, along which topography was sketched, was run between bench-marks, and generally the lines throughout were straight; but sometimes it was found necessary to make one or more angles in a line in order to get a favorable location for a bench-mark.

Every bench-mark, when it was possible, was referred to some point in the Government land surveys. Most of the lines, besides, were connected by a stadia line with the secondary triangulation, which was at this time being carried on in advance of the bench-mark work.

During the first part of the work the object had in view was to obtain information by which the lines and bench-marks could be laid down on the large maps of the survey of 1878 and 1879. In some instances, therefore, when this information was obtained while running the line, and when it would involve considerable loss of time to connect with the triangulation, the connection was omitted. Toward the close of the season, however, the Commission ordered a new shore-line survey, which was to be the basis for a new map and to which the topography on the old maps of 1878 and 1879 is to be transferred. As the principal, and almost only, links by which the topography of the old maps can be connected with the new is the bench-mark lines that have a connection with the secondary triangulation, it will probably be found necessary to have the omitted connections yet made.

Elevations derived from the temporary bench-marks established in 1880 and 1881 were transferred to the permanent bench-marks, all levels being carefully checked. The checks were made by each levelman running back over his own line, using new turning-pegs for his return work, or driving down the old ones before using them. In this way no close comparison could be made between first and check lines until the starting point was reached. The requirements were that the two lines should agree within 0'.010 in a distance of 1 mile. The results, which have been given in the weekly reports, and which, in most cases, were even better than the requirements, show that great care was exercised; and the subsequent reduction of the notes confirms the belief that reliance may be placed on the work.

It was found during the first month that the level party, which consisted of tw levelmen and necessary assistants, was steadily falling behind the locating party. On the 1st of August, therefore, a third level was added. This enabled the party to more nearly keep pace with the location.

During the summer of 1889, thirty-five permanent bench-marks, on lines 83 to 95, both inclusive, were established and their elevations determined under the direction of Division Engineer S. W. Fox; but they were left unlocated except in quite general terms. These lines were therefore located by us in the same manner as the other lines, namely, by measuring between bench-marks and connecting the lines with the triangulation. While this work was in progress, the level parties finished work above, and, passing over the space covered by these lines, joined the locating party near the end, both parties finishing the season's work about the same time.

The work accomplished was as follows:

River covered, not including that covered by Division Engineer Fox's work ....miles..	306
Including Fox's work ....do...	384
Bench-mark line and connection with the triangulation ....do...	337.23
Levels run and checked ....do...	382.83
Number of—	
bench-mark lines established	48
permanent bench-marks set	128
permanent bench-marks located (previously established by Division Engineer Fox)	35

The cost of the field work, not including cost of stone and pipe and quarter boats was as follows:

Pay rolls		$5,468.87
Subsistence stores purchased on vouchers	$1,134.97	
Purchased on so-called subsistence vouchers	175.00	
	1,309.97	
Deduct for stores transferred to Division Engineer S. H. Yonge..	162.62	
		1,147.35
Tools and other supplies		178.82
Traveling expenses		29.90
Total		6,824.94

The number of rations consumed was 3,680; cost per ration, $0.312.

Sixteen days were spent in locating the permanent bench marks established by Division Engineer Fox in 1889.

Cost for the 16 days, about $437. This, deducted from the total cost, gives $6,387.94 as expense in the field of establishing complete the 128 permanent bench-marks, not including cost of stone and pipe and quarter-boats.

Cost per mile of river (306 miles)	$20.87
Cost per B. M. line	133.08
Cost per permanent B. M	49.67

About eight days were lost on account of wind, which prevented the quarter boat from being moved, and 4 days on account of rain.

Of the 41 bench-marks of 1880 between Sioux City and Omaha, only one could be found, and that one (a few miles above Blair, Nebr.) had the appearance of having been tampered with, and was not used, except to test its elevation in passing. A difference of 0.676 foot was found between its elevation, as established in 1880, and the elevation as carried down from Sioux City by the party last season, the elevation 1880 being that much higher.

Of the 156 bench-marks of 1880 and 1881, between Omaha and Fort Leavenworth, search was made for 47. Of these, 33 were found intact, 7 had been destroyed, 3 had rotted out, and 4 could not be found.

Of those found, 10 were on foundations of buildings or bridges, 7 on elm tre bolts in rock, 3 on black-walnut trees, 3 on cottonwood, 3 on oak, 1 on maple, 1 on and 2 gas-pipe in cement. Of those rotted, 2 were on black-walnut trees and cottonwood.

No old bench-marks of 1880 and 1881 were looked for between White Cloud, K and Atchison, that portion being covered by the work done by Division Enginee in 1889.

Since the close of the field work the bench-marks have been plotted on the maps of the survey of 1878 and 1879, and the topography along the lines sketche pencil.

The level notes have been reduced, and elevations, referred to the bench marks of 1880 and 1881, ascertained.

Two independent reductions, by different parties, have been made of the notes of the work below Omaha, with identical results.

Between Omaha and Sioux City three separate reductions have been made, and some slight differences in the first two reductions satisfactorily explained.

The method used in the reduction was: First, to find the difference in elevation between two points as shown by the first level line; second, find the difference as shown by the check levels run in the opposite direction; then, as a rule, take the mean of the two differences as the true difference of elevation between the points. These differences, added to or subtracted from—as the case may require—the known elevation of the starting point, gives the true elevation for all points on the line.

The accompanying table shows the elevation, referred to the St. Louis City Directrix, of the permanent bench-marks established during the season; it also shows the difference in elevation of consecutive bench-marks.

Bench-marks $\frac{83}{1}$ to $\frac{96}{2}$, both inclusive, are omitted from the table, their elevations having been determined by Division Engineer Fox and published in the report of the Commission for 1889.

The origin of the levels by which the elevations have been determined is the old bench-marks of 1880 and 1881, the elevations of which are shown in the table in parentheses. The elevation of each permanent bench-mark is derived from that of bench-mark of 1880 or 1881, shown next preceding it in the table, except from $\frac{146}{1}$ to $\frac{143}{1}$, whose elevations are derived from B. M. 466 "A" a of 1880, which appears near the bottom of the table.

A list of the permanent bench-marks established during the season, as well as those established by Division Engineer Fox in 1889, with elevations and description of their location, is also submitted.

In regard to the discrepancy found at the old bench-mark of 1880 hereinbefore mentioned, it is probably due to a difference, more or less great, to be expected between two lines of levels run and checked by different methods over a distance of 90 and 189 miles, respectively. The distance run in 1880 from Sioux City to the point in question is about 90 miles, the run being all on one side of and along the river, while last season, the levels being carried through all the bench-marks between the same points, the distance was 189 miles.

In 1880 the levels were checked by a second level following the first, both running on the same turning pegs, and comparing results at short intervals. A reference to the notes of that work shows that, starting together, their elevations gradually ran apart until, at the end of 46 miles, that by the first level was 0.092 foot higher than that of the second; at 53 miles the first level was 0.046 foot lower than the second; and at 62 miles, again 0.019 foot higher.

By this method of checking it is doubtful if unbiased results can be obtained. Two levelmen, finding that they are running apart, will, however honest they may be in intention, unconsciously squeeze their work in the wished-for direction.

By the method of each levelman running over his own work in the opposite direction personal equation is eliminated, which is not the case in the former method; and if care is used in the manipulation of the instrument the results ought to approximate to accuracy. It would seem, therefore, that of the two results here compared that of the past season should be given preference.

Wherever the words bench-mark or letters "B. M." are used in this report reference is made to the permanent bench-marks, which are designated fractionally, the numerator standing for the number of the bench-mark line, counting from the mouth of the river up, and the denominator for the number in the line, counting from the one on the right bank farthest from the river. The old bench-marks from which eletations are derived, when mentioned, are distinguished by the years 1880 or 1881.

The level work was under the immediate charge of Capt. I. D. McKown. I take pleasure in testifying to his zeal, energy, and general efficiency.

Very respectfully, your obedient servant,

D. W. WELLMAN,
Assistant Engineer.

eut. J. C. SANFORD,
Secretary Missouri River Commission.

Descriptions and elevations, referred to the St. Louis City directrix, of permanent bench-marks between Fort Leavenworth, Kans., and Sioux City, Iowa, established in the summer of 1890. Distances above mouth from survey of 1879.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{79}{1}$	About 2¼ miles, measuring along the bluff, above the Chicago, Rock Island and Pacific Railroad Bridge at Fort Leavenworth, at south fence of right of way Missouri Pacific Railroad, and 350 feet west of head block of siding. House of George Buchanan, on Kickagoo Island, bears N. 40° E. (mag.) about 2,300 feet	355.650	
$\frac{79}{2}$	On Kickapoo Island, 510 feet west of southwest corner of sec. 36, on land owned by —— Anderson	351.487	
$\frac{80}{1}$ Weston.	At Weston, Mo., on Kansas City, St. Joseph and Council Bluff Railroad depot ground, 14 feet east of northeast corner of depot building	356.565	424.6
$\frac{81}{1}$ Kickapoo.	At Kickapoo, Kans., on west side of ravine, 40 feet from small stream in ravine 86 feet south of Missouri Pacific trestle bridge. George Sharp's house bears S. 88° W. (mag.) 130 feet distant	387.850	428.7
$\frac{81}{2}$	On left bank, about 1¼ miles N. 30½° E. (mag.) from $\frac{81}{1}$ on south side of east-and-west road, 760 feet east of northwest corner of NW. ¼ of SW. ¼ sec. 9, T. 53, R. 36 W	355.077	
$\frac{81}{3}$	On continuation of line $\frac{81}{1}$ to $\frac{81}{2}$ at south right-of-way fence Kansas City, St. Joseph and Council Bluff Railroad, 760 feet west along railroad track from east-and-west lane, which lane is on line through center of sec. 4, T. 53 N., R. 56 W	364.338	
$\frac{82}{1}$ Oak Mills.	At Oak Mills, Kans., in yard of John Davitz, 19 feet east of his store	367.467	440.0
$\frac{82}{2}$ Iatan.	At Iatan, Mo., on small knoll, 55 feet north of Kansas City, St. Joseph and Council Bluffs Railroad track, on south side of wagon road along bluff. Railroad depot bears S. 61° 10′ E. (mag.) 338 feet distant	388,104	433.6
$\frac{83}{1}$ Walnut Creek.	About 4½ miles above Oak Mills, Kans., near south line of sec. 28, T. 6 S., R. 21 E. is 136 feet S. 18° 40′ E. (mag.) from center Missouri Pacific bridge over Walnut Creek, at foot of bluff	371.429	430.5
$\frac{83}{2}$	On left bank, at foot of bluff 1 mile south of Sugar Lake Station, Kansas City, St. Joseph and Council Bluffs Railroad, 236 feet N. 63¾° W. (mag.) from J. P. Coleman's house, 1,445 feet N. 20° 20′ E. (mag.) from center sec. 2, T. 54 N., R. 37 W	383.711	
$\frac{84}{1}$ Atchison.	At Atchison, Kans., on west side of Gillespie street, 710 feet south of its intersection with Park street	385.052	445.8
$\frac{84}{2}$	One and one-half miles east of Winthrop, Mo., 339 feet south of corner secs. 19, 20, 29, 30, T. 55 N., R. 37 W	369.691	
$\frac{84}{3}$	About 3¾ miles east of Winthrop, Mo., at foot of bluff near north line of sec. 27, T. 55 N., R. 37 W., 284 feet, N. 37½° E. (mag.) from house of Ben Moore	383.003	
$\frac{85}{1}$	About 2½ miles along railroad track below Doniphan, Kans., 1,460 feet above residence of Mrs. Scott, 67 feet west of railroad track, at foot of bluff	377.134	450.3
$\frac{85}{2}$	On left bank, 2¼ miles S. 77½° E. (mag.) from $\frac{85}{1}$ on south side of wagon road, opposite house of Melvin Pendergrass. It is 739 feet west of the east ¼ post of sec. 9, T. 55 N., R. 37 W	376.356	
$\frac{85}{3}$ Rushville.	On south side of Rushville, Mo., at foot of bluff on east side of wagon road, 154 feet south of its intersection with branch of Rock Island Railroad	393.254	
$\frac{86}{1}$	About 2 miles below Geary City, Kans., at foot of bluff on west side of wagon road, and 155 feet S. 80° W. (mag.) from schoolhouse. The SE. corner of NE.* ¼ sec. 3 bears N. 85½° E. (mag.) 1,650 feet distant	388.615	460.5
$\frac{86}{2}$	On left bank, about 2 miles below Hall's Station, Kansas City, St. Joseph and Council Bluffs Railroad, on side of bluff, 51 feet south of road running along bluff, and opposite end of north and south road running toward the bluff. It is about 15 feet higher than the bottom lands	392.957	
$\frac{87}{1}$	Two and one-quarter miles along bluff above Geary City, Kans. Is near north line of sec. 30, T. 4 S., R. 22 E., and about 600 feet west of the north ¼ post of section. Is 87 feet northwest from small road bridge at foot of bluff	407.388	
$\frac{87}{2}$	Is 2,000 feet northeast of Kenmoor Station, on Chicago, Rock Island and Pacific Railroad, about 250 feet northeast of house of Warren Samuels. Is in northeast corner sec. 28, T. 56 N., R. 36 W	404.750	
$\frac{88}{1}$ Palermo.	In Palermo, Kans., 98 feet northeast of house of Dr. Harrington	403.223	472.1
$\frac{88}{2}$	On left bank, 3¾ miles down the railroad from the Hannibal and St. Joseph Railroad bridge, at St. Joseph, Mo., one-half mile east of the railroad, 304 feet southwest from house of Nelson Hawley. It is near quarter post on north side of sec. 12, T. 56 N., R. 36 W	412.086	

* There is some uncertainty about this corner.

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{89}{1}$ Wathena.	In town of Wathena, Kans., on west line of Bryant street at intersection with alley south of St. Joseph street	409.311	
$\frac{89}{2}$	On right bank, about 2½ miles east of Wathena, Kans., on north side of wagon road, at corner secs. 25, 26, 35, 36, T. 3 S., R. 22 E.	398.586	
$\frac{89}{3}$ St. Joseph.	In city of St. Joseph, Mo., at northeast corner of Bartlett and Duncan streets, about 1,100 feet easterly from east end of Hannibal and St. Joseph Railroad bridge	407.035	479.5
89½ United States boat yard.	On left bank, at United States boat yard, 3 miles above St. Joseph, Mo., 65 feet below lower end of United States ways, a few feet from top of revetment. It is near the north line of sec. 1, T. 57 N., R. 37 W., about 800 feet east of the northwest corner of the section	403.900	
$\frac{90}{1}$	Three miles above Belmont, Kans., at foot of bluff, 1,225 feet south of house of Lucas Fedder, near corner of secs. 2, 3, 10, 11, T. 3 S., R. 22 E.	407.977	487.7
$\frac{90}{2}$	About 3½ miles above St. Joseph, Mo., 715 feet north of the pump house, St. Joseph Water Works Co., and 65 feet east of track Kansas City, St. Joseph and Council Bluffs Railroad	407.182	495.0
$\frac{91}{1}$ Cummings Landing	At Cummings Landing, Kans., on south side of section line road, 430 feet southeast from house of Nathan Miller. It is 128 feet west of the southeast corner of the SW. ¼ of SE. ¼, sec. 21, T. 2 S., R. 22 E	442.237	502.8
$\frac{91}{2}$	On left bank, about 2 miles below Amazonia, Mo., on south side of east-and-west road, 380 feet northeast of north end of Kansas City, St. Joseph and Council Bluffs Railroad trestle bridge over Dillon Creek in NW. ¼, sec. 7, T. 58 N., R. 36 W.	417.034	
$\frac{92}{1}=\frac{91}{1}$		442.237	502.8
$\frac{92}{2}$	On left bank, about 2½ miles west of Amazonia, Mo., 1,380 feet N. 9° 30′ W. (mag.) from house of A. Rencer. It is 145 feet east of NW. corner of SW. ¼ of SW. ¼, sec. 34, T. 59 N., R. 36 W	415.653	
$\frac{92}{3}$	About 2½ miles northwest of Amazonia, Mo., at foot of bluff, 525 feet north of Kansas City, St. Joseph and Council Bluffs Railroad, 156 feet S. 81° 45′ E. (mag.) from house of Louis Payne, near center of sec. 27, T. 59 N., R. 36 W	420.431	
$\frac{93}{1}$	About 2 miles below Charleston City, Kans., at foot of bluff, about 50 feet east of small ravine. Is about 12 feet in elevation higher than the bottom land. It is in SW. ¼, sec. 24, T. 2 S., R. 21 E	422.370	
$\frac{93}{2}$	On right bank, about three-fourths of a mile north of $\frac{93}{1}$, on north side of wagon road, in edge of small orchard, 140 feet southeast from house of E. S. Jennings, 860 feet west of center sec. 13, T. 2 S., R. 21 E	418.692	
$\frac{93}{3}$	About 2½ miles west of Nodaway, Mo., on small mound on point of bluff, 90 feet north of Kansas City, St. Joseph and Council Bluffs Railroad, 25 feet east of small log cabin at mouth of narrow valley and opposite siding for loading wood	340.622	508.5
$\frac{94}{1}$ Mt. Vernon.	At Mt. Vernon Landing, at lower point of bluff where it turns up the valley, 60 feet from river bank, 500 feet above the mouth of Musquito Creek	432.062	515.0
$\frac{94}{2}$	On left bank, 4,270 feet N. 70° E. (mag.) from $\frac{94}{1}$, on north side of road running along old river bank, 700 feet east of house of James L. Wilson, near north and south half section line running through sec. 6, T. 58 N., R. 37 W	422.607	
$\frac{94}{3}$ Forbes.	On north side of Kansas City, St. Joseph and Council Bluffs Railroad, 1,450 feet west of depot at Forbes, Mo., 10 feet north of right of way fence	441.185	
$\frac{95}{1}$ Wolf Creek.	In the woods, at foot of bluff, about three-fourths of a mile below the mouth of Wolf Creek, in NE. ¼ sec. 9, T. 2 S., R. 20 E., approximately 1,000 feet west of the east line, and 600 feet south of north line of the section	426.641	520.0
$\frac{95}{2}$	On left bank, about 1½ miles N. 22° E. (mag.) from $\frac{95}{1}$, 300 feet southeast from house of George Quick, 200 feet east of section line road, 1,468 feet N. 0° 15′ E. (mag.) from SW. corner sec. 22, T. 59 N., R. 38 W	422.904	
$\frac{95}{3}$	About 4½ miles west of Forbes Station on Kansas City, St. Joseph and Council Bluffs Railroad, at foot of bluff, 125 feet north of railroad. It is 2,860 feet east of east end of platform at Curzon Switch, 435 feet southeast of house of J. Elder, near south line of NE. ¼ sec. 15, T. 59 N., R. 38 W	434.781	
$\frac{96}{1}$ Iowa Point.	At Iowa Point, Kans., at northwest corner of Main and Commercial streets	441.226	524.0
$\frac{96}{2}$	About 1½ miles southeast of Forest City, Mo., at foot of bluff, 600 feet east of Kansas City, St. Joseph and Council Bluffs Railroad, 50 feet west of house of W. F. Davis. It is near the center of sec. 4, T. 59 N., R. 38 W	449.024	
$\frac{97}{1}$ White Cloud.	In White Cloud, Kans., in northwest corner of dooryard of Charles Osgood, on south side of Main street, 150 feet west of west line of Second street	471.045	530.8
$\frac{97}{2}$	On left bank, 1½ miles N. 27½° E. (mag.), from $\frac{97}{1}$, at side of road, 325 feet east of center of sec. 28, T. 60 N., R. 39 W	431.329	

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
${}^{97}_{3}$	On line from ${}^{97}_{1}$ to ${}^{97}_{2}$ produced, and 5,782 feet distant from ${}^{97}_{2}$ at east-and-west fence, 97 feet west of fence corner. It is in SW. ¼ sec. 22, T. 60 N., R. 39 W., about 2,200 feet N. 23° E. (mag.) from southwest corner of section on land owned by A. W. Van Kamp	430.255	
${}^{98}_{1}$	About one-half mile north of State line between Kansas and Nebraska, at foot of bluff, at north side of wide ravine. It is 132 feet west of railroad on small plateau (former site of farm house), 86 feet from a magnificent elm tree 3 feet in diameter	465.814	
${}^{98}_{2}$	On left bank, 1¼ miles from ${}^{98}_{1}$, on east side of north-and-south road, 900 feet south of NW. corner of sec. 17, T. 60 N., R. 39 W. Land owned by Phillip Davis	435.684	
${}^{98}_{3}$	About 1½ miles from ${}^{98}_{2}$, in fence corner on south side of east-and-west road, 1,320 feet east of NW. corner of sec. 9, T. 60 N., R. 39 W., 240 feet east of house of William Allkrie	434.798	
${}^{99}_{1}$ Rulo.	At Rulo, Nebr., in dooryard of John Stull, at west side of Commercial street, and 170 feet south of south line of Stutzen street, about 1,500 feet below railroad bridge	445.815	542.0
${}^{99}_{2}$	On left bank, 1½ miles from ${}^{99}_{1}$, on west side of north-and-south road and 400 feet north of B. & M. Railroad, about 7,600 feet from east pier of Rulo bridge	442.949	
${}^{99}_{3}$	About seven-eighths mile from ${}^{99}_{2}$, in NE. ¼ sec. 26, T. 61 N., R. 40 W., on west side of north-and-south road, 150 feet north of SE. corner of SW. ¼ of NE. ¼ of section. It is 33 feet north of schoolhouse, district No. 50	444.762	
${}^{100}_{1}$	Three miles below Arago, Nebr., in woods at foot of bluff, 4 feet south of fence on north line of sec. 30, T. 1 N., R. 15 E., 1,330 feet N. 2° E. (mag.) from R. K. Durfee's brick dwelling house	452.886	549.0
${}^{100}_{2}$	On left bank, 1¼ mile from river bank, on west side of north-and-south road, 1,500 feet south of NE. corner sec. 3, T. 61 N., R. 40 W., on land owned by David Perkins	494.305	
${}^{100}_{3}$	Is 5,660 feet from ${}^{100}_{2}$, on east side of north-and-south road, 50 feet north of SW. corner sec. 36, T. 62 N., R. 40 W. Land owned by Edward Vest	448.742	
${}^{101}_{1}$ Arago.	In Arago, Nebr., in corner of dooryard of Charles Stricker, south side of Main street, 820 feet from river	492.817	552.0
${}^{101}_{2}$	On left bank, about 1¼ miles N. 45° E. (mag.) from ${}^{101}_{1}$, on east side of north-and-south road, 374 feet south of W. ¼ post of sec. 21, T. 62 N., R. 40 W., in southwest corner of dooryard of Henry Voltmers	458.238	
${}^{101}_{3}$	One and one-quarter miles from ${}^{101}_{2}$, 790 feet north of corner secs. 15, 16, 21, 22, T. 62 N., R. 40 W., on west side of north-and-south hedge fence. Land owned by George Voltmers	454.126	
${}^{102}_{1}$	About 4¾ miles above Arago, Nebr., at foot of bluff, at side of wagon road leading from river up narrow valley, 300 feet above mouth of creek, 120 feet from the river. Large house one-fourth mile up the valley belongs to Cottier	461.250	558.3
${}^{102}_{2}$	On left bank, opposite ${}^{102}_{1}$, about 2 miles distant, on section line, 1,036 feet north of SW. corner sec. 31, T. 63 N., R. 40 W., on land owned by William Fork	457.107	
${}^{102}_{3}$	On continuation of line ${}^{102}_{1}$ to ${}^{102}_{2}$ and seven-eighths mile from ${}^{102}_{2}$, on west side of north-and-south road, 562 feet north of SE. corner of SW. ¼ of NE. ¼ sec. 31, T. 63 N., R. 40 W., on land owned by Dr. Anderson	459.563	
${}^{103}_{1}$ St. Deroin.	At St. Deroin, Nebr., in southeast corner of dooryard of Allen Woodring, at west side of Nebraska street, 450 feet from the river bank	465.474	565.8
${}^{103}_{2}$	On left bank, 1½ miles N. 13° E. (mag.) from ${}^{103}_{1}$, on north side of east-and-west road, 246 feet west of SE. corner of SW. ¼ sec. 5, T. 63 N., R. 41 W. It is 180 feet N. 64½° W. (mag.) from Lincoln schoolhouse	463.625	
${}^{103}_{3}$	About 1 mile northeast from ${}^{103}_{2}$, at fence corner, at southwest angle formed by intersection of east-and-west and north-and-south roads, one-fourth mile west of SE. corner sec. 32, T. 64 N., R. 41 W. Land owned by F. W. Walters	462.797	
${}^{104}_{1}$	Three miles above St. Deroin, at Hillsdale, Nebr., in southeast corner of dooryard of L. J. Slagle, 24 feet north of his house on west side of north-and-south road, 440 feet from river	477.208	5[illegible].1
${}^{104}_{2}$	On left bank, in dooryard of E. Rosenbaugh, 685 feet east of SW. corner of SE. ¼ sec. 24, T. 64 N., R. 42 W., on north side of east-and-west road	468.502	
${}^{105}_{1}$ Nemaha City.	About three-fourths mile above Nemaha City, Nebr., at foot of bluff, 100 feet west of B. & M. Railroad track, in yard of premises owned by William Hoover	482.825	5[illegible].7
${}^{105}_{2}$	On left bank, 1½ miles from ${}^{105}_{1}$, on east side of north-and-south road, 740 feet north of SW. corner of NE. ¼ sec. 27, T. 64 N., R. 42 W	470.197	

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{105}{3}$	About seven-eighths mile east of $\frac{105}{2}$, 1,344 feet east of west ¼ post of sec. 26, T. 64 N., R. 42 W., in dooryard of premises owned by T. W. Wilker	469.664	
$\frac{106}{1}$ Brownville.	At Brownville, Nebr., at northwest corner of Main street and Levee, 122 feet northwest from railroad depot	492.260	580.0
$\frac{106}{2}$	On left bank, 780 feet west of NE. corner of SE. ¼ sec. 34, T. 47 N., R. 42 W., at south side of east-and-west road, in dooryard of B. A. De Buhr	473.369	
$\frac{106}{3}$ Phelps.	At town of Phelps, Mo., in NE. corner of the Methodist Church yard, at north end of Main street	474.876	
$\frac{107}{1}$ Sonora Island.	About 4 miles, measuring along the railroad above Brownville, Nebr., 1,650 feet west of railroad, at foot of bluff, 50 feet north of Honey Creek, 190 feet east of Henry Coles' house, in fence corner where road turns west	485.306	
$\frac{107}{2}$ Sonora.	On left bank, 1 mile from the river, opposite head of Sonora Island, in corner of barn yard belonging to heirs of H. H. Hays. Is 27 feet north of ¼ post, common to secs. 3 and 4, T. 65 N., R. 42 W	484.002	584.0
$\frac{108}{1}$ Peru.	In Peru, Nebr., in NE. corner of door yard of John C. Wayne, on west side of Fifth street, 150 feet north of Mulberry street	496.161	588.1
$\frac{108}{2}$	On right bank, 1¼ miles north and one-fourth mile east of $\frac{108}{1}$, on east side of road running through the eastern part of sec. 9, T. 6 N., R. 15 E., and 1,202 feet north of line through the center of the section, 50 feet north of house owned by Robt. Rader	487.304	
$\frac{109}{1}$	About 1¼ miles below Otoe City (Minersville), Nebr., at foot of bluff, in door yard of premises owned by Mr. Coe, 66 feet west of railroad track, 2,860 feet below (south of) section house. Section house is 1 mile below Otoe City	496.458	598.2
$\frac{109}{2}$ Missouri and Iowa State Line.	On left bank, on north side of State line road between Missouri and Iowa, about 1,200 feet west of east line of sec. 34, T. 67 N., R. 43 W., in southeast corner of orchard belonging to Oliver Taylor	498.838	
$\frac{109}{3}$	Is 6,380 feet east of $\frac{109}{2}$, on south side of State Line road, in southeast angle of fence formed by intersection of north-and-south and east-and-west roads. Premises owned by Joseph Payne	492.742	
$\frac{110}{1}$	About 1¼ miles above Otoe City, Nebr., near NE. corner of SW. ¼ of SW. ¼ sec. 36, T. 8 N., R. 14 E., at west fence of railroad right of way, on premises owned by McGuire	500.186	
$\frac{110}{2}$	On left bank, 3¾ miles above Hamburg, Iowa, 300 feet west of Kansas City, St. Joseph and Council Bluffs Railroad near the SE. corner of sec. 12, T. 67 N., R. 43 W., on north side of east-and-west road a few feet west of schoolhouse	493.023	
$\frac{110}{3}$	About 1 mile east of $\frac{110}{2}$, near the corner of secs. 7, 8, 17, 18, T. 67 N., R. 42 W., at northwest corner of inclosed pasture about 600 feet S., 6½° E. (mag.) from the house owned by Moses Payne	491.366	
$\frac{111}{1}$ Nebraska City.	At Nebraska City, Nebr., at northwest corner of First street and Central avenue, on lot owned by Nebraska City Gas Company	532.078	609.0
$\frac{111}{2}$ Nebraska City.	On left bank, opposite Nebraska City, at United States boat yard, 70 feet north of the ways, and 90 feet from the river bank	505.416	
$\frac{112}{1}$ Walnut Creek	About 3½ miles above Nebraska City, Nebr., at foot of bluff, 900 feet from the river, opposite the mouth of a small stream known as Walnut Creek, in dooryard of John Roddy on SE. ¼, sec. 30, T. 9 N., R. 14 E	592.690	615.0
$\frac{112}{2}$	On left bank, 2 miles from $\frac{112}{1}$, on west side of north-and-south road, in NE. ¼ sec. 1, T. 68 N., R. 44 W., 665 feet south of north line of the ¼, and 500 feet east of the west line of the ¼, 610 feet south of the house of Paul Heinlin	512.681	
$\frac{113}{1}$ Wyoming.	A half mile below Wyoming, Nebr., 180 feet from the river bank, on small elevation in dooryard of Edward W. Neligh, 160 feet south of small spring brook	537.483	617.8
$\frac{113}{2}$	On left bank, 1⅝ miles from $\frac{113}{1}$, in yard of Delos Williams, 75 feet south of east-and-west road, 667 feet west of NE. corner of NW. ¼ sec. 30, T. 69 N., R. 44 W	515.754	
$\frac{113}{3}$	About 1¼ miles east of $\frac{113}{2}$, in NE. corner of sec. 30, T. 69 N., R. 43 W., in dooryard of F. E. Wadhams	516.197	
$\frac{114}{1}$ Jones Point.	At Jones Point, Nebr., at lower end of bluff where it turns west, 490 feet from the river bank, in corner of field 15 feet south of the road. It is in SW. ¼ of sec. 28, T. 10 N., R. 14 E. The southwest corner of the section is about one-third mile southwest	523.838	622.5
$\frac{114}{2}$	On left bank, about 1¼ miles east of $\frac{114}{1}$, on east side of north-and-south road, 810 feet north of SW. corner of sec. 5, T. 69 N., R. 43 W	518.434	

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{114}{3}$	Is 2,559 feet east of $\frac{114}{2}$, on west side of north-and-south road, on west side of hedge fence, 690 feet north of the SE. corner of SW ¼ sec. 5, T. 69 N., R. 43 W	518.576	
$\frac{115}{1}$	About 5½ miles, measuring along the bluff above Jones Point, Nebr., 60 feet from the river, at foot of bluff, at the lower side of a small valley, about 200 feet south of the east-and-west ½ section line through sec. 33, T. 11 N., R. 14 E., on south side of small creek. H. W. Cory's house is up the valley about 500 feet	539.142	528.2
$\frac{115}{2}$	On left bank 1¾ miles from $\frac{115}{1}$, on east side of north-and-south road, and 45 feet east of NW. corner of NE. ¼ sec. 17, T. 70 N., R. 43 W	526.499	
$\frac{116}{1}$ Rock Bluff.	At Rock Bluff, Nebr., 15 feet east of the NW. corner of second and Main streets, in dooryard of R. Churchill	555.385	632.4
$\frac{116}{2}$	On left bank, 5.831 feet nearly due east from $\frac{116}{1}$, on west side of road running along an old river bank. Is not far from the center of NE. ¼ of NE. ¼ sec. 30, T. 71 N., R. 43 W	532.082	
$\frac{116}{3}$	About 1¼ miles east, and one-fourth mile north of $\frac{116}{2}$, about 1,000 feet west of Kansas City, St. Joseph and Council Bluffs Railroad, 880 feet N. 72° 45′ E. (mag.) from SW. corner of sec. 21, T. 71 N., R. 43 W., at east side of road running along top of bank of old lake bed. Land owned by heirs of Thomas Conners	531.639	
$\frac{117}{1}$ Plattsmouth.	At Plattsmouth (Nebr.) Railroad bridge, 10 feet south, and on line with first trestle bent west of the west end of the bridge	540.020	638.3
$\frac{117}{2}$	On left bank, 1⅜ miles east of $\frac{117}{1}$ on south side of east-and-west road, 128 feet east and 40 feet south of NW. corner of sec. 31, T. 72 N., R. 43 W., in dooryard of Mrs. Lizzie Green.	538.794	
$\frac{117}{3}$	Is 1¾ miles east of $\frac{117}{2}$, on east side of north-and-south road, and south side of east-and-west road, in yard of premises owned by Mr. Crun, of Pacific Junction. It is near north line of sec. 32, T. 72 N., R. 43 W., one-fourth mile east of the north ¼ post of the section	538.109	
$\frac{118}{1}$ Platte River.	About 3¼ miles, measuring along the bluff, above Plattsmouth, Nebr., at foot of bluff, 2,610 feet. S. 45° 50′ E. (mag.) from NW. corner sec. 1, T. 12 N., R. 13 E	573.391	
$\frac{118}{2}$	On left bank, about 3⅜ miles N. 62° E, (mag.) from $\frac{118}{1}$, 1¼ miles from the river. Is on west side of north-and-south road, 1,010 feet south of NE. corner of sec. 12, T. 72 N., R. 44 W., on land owned by Alvin Lincoln	539.780	
$\frac{119}{1}$ Belleone.	At Belleone, Nebr., 90 feet west of north end of railroad station	559.268	652.0
$\frac{119}{2}$	On left bank, 1⅝ miles east of $\frac{119}{1}$, one-fourth mile east and 430 feet south of NW. corner of sec. 12, T. 73 N., R. 44 W., on the east side of old stage road, about 300 feet north of house of J. C. Cole	548.206	
$\frac{119}{3}$	Is 1⅝ miles east of $\frac{119}{2}$. It is on south line of sec. 6, T. 73 N., R. 43 W., 603 feet east of SW. corner of SE. ¼ of SE. ¼ of the section, in dooryard of C. H. W. Busse	555.801	
$\frac{120}{1}$	About 4½ miles below Union Pacific Railroad bridge at Omaha, Nebr., one-fourth mile north of line between Sarpy and Douglas counties, 200 feet west of B. & M. Railroad, on south slope of narrow ravine	590.168	
$\frac{121}{1}$ Omaha.	In Omaha, Nebr., in northeast corner of Union Pacific office premises, 99 feet from office building, which is on corner of Ninth and Farnham streets	602.653	668.0
$\frac{121}{2}$ Council Bluffs.	In Council Bluffs, Iowa, in southwest corner of county court-house yard	577.156	
$\frac{122}{1}$	In North Omaha, 286 feet east of railroad depot, in corner of yard of Mrs. Louisa Hillike, at corner of Sixteenth street and Garfield avenue	569.485	
$\frac{122}{2}$	On left bank, at United States boatyard, near Council Bluffs, Iowa, at upper end of ways, 100 feet from river bank	562.154	
$\frac{123}{1}$	At Florence, Nebr., on ground of the water-works company, between the pump house and the river, 115 feet from the pump house	590.290	671.3
$\frac{123}{2}$	On left bank, about 3 miles east of Florence, Nebr., at intersection of north-and-south and east-and-west roads, in the northwest corner of C. E. Osborn's yard in the SW. ¼ of NW. ¼ sec. 34, T. 76 N., R. 44 W., and near the northwest corner of the same	570.850	
$\frac{124}{1}$ Rockport.	Near site of Old Rockport, Nebr., on small plateau near edge of bluff, about ¼ mile north of the line between Douglas and Washington counties, Nebr., on the east side of road which winds up the hill on north side of narrow valley, on land of ——— Parker	599.795	68 5
$\frac{124}{2}$	On left bank, about 1⅝ miles east of $\frac{124}{1}$, on south side of road, 352 feet S. 79° 55′ E. (mag.) from center of sec. 9, T. 76 N., R. 44 W., on land owned by ——— Corby	570.212	

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{125}{1}$ Fort Calhoun.	At Old Fort Calhoun, Nebr., 800 feet south of the site of the old fort, in corner of yard of A. M. Beals. It is 650 feet N. 1° W. (mag.) from south ½ post of sec. 12, T. 17 N., R. 12 E.	651.052	690.0
$\frac{126}{1}$ De Soto.	At De Soto, Nebr., in angle of east-and-west and north-and-south roads, about 250 feet northeast from J. E. Markel's house in SE. ¼ sec. 28, T. 18 N., R. 12 E., 890 feet west of east line and 1,300 feet north of south line of section	603.142	
$\frac{126}{2}$	On left bank, opposite De Soto, about 1¼ miles from the river bank. Is in southwest corner of sec. 25, T. 78 N., R. 45 W. H. B. Hendrick's house is on opposite side of road, about 200 feet distant	584.812	
$\frac{127}{1}$ Blair.	In town of Blair, Nebr., in southeast corner of dooryard of H. L. Fisher, at corner of Seventh and Washington streets	663.804	
$\frac{127}{2}$	Is a mark thus $\underset{\text{U.S.}}{\square}$ cut on top of coping, on north end of west pier of Blair railroad bridge	636.238	
$\frac{127}{3}$	At California Junction, Iowa, in northwest corner of orchard of A. W. Smith, about 750 feet east of depot at California Junction. It is 256 feet south of the NW. corner of SW. ¼ sec. 14, T. 78 N., R. 45 W	588.833	
$\frac{128}{1}$	About 5 miles north of Blair, Nebr., on SE. ¼ sec. 14, T. 19 N., R. 11 E., 1,300 feet north of the southwest corner of the quarter. It is on the base line measured at that place for the secondary triangulation, Missouri River survey. Is 8,790 feet west of East Base station on land owned by W. Tyson	594.933	
$\frac{128}{2}$	On right bank, 1 mile east of $\frac{128}{1}$, on same base line, 3,417 feet west of East Base station, on east side of north-and-south road, one-fourth of a mile north of south quarter post of sec. 13, T. 19 N., R. 11 E., one-fourth of a mile south of W. Tyson's house	599.873	711 5
$\frac{128}{3}$	On left bank, about 3¼ miles northeast of $\frac{128}{2}$, between Soldier River and Horse Shoe Lake, on north side of east-and-west road, 150 feet west of one-quarter post between secs. 22 and 27, T. 79 N., R. 45 W	598.290	
$\frac{129}{1}$	On county line between Burt and Washington counties, Nebr., 1 foot from stone marking corner of secs. 22, 23, 26, 27, T. 20 N., R. 11 E	600.723	
$\frac{129}{2}$	On right bank, on county line, 4,345 feet due east from $\frac{129}{1}$, at end of private lane and top of old river bank	602.912	716.3
$\frac{129}{3}$	On left bank, opposite $\frac{129}{2}$, 2 miles from the river, on west side of section line road between secs. 3 and 4, T. 79 N., R. 45 W., 1,208 feet south of northeast corner of section 4. Land owned by John Harrington	600.238	
$\frac{130}{1}$	Is 4 miles north of the south line of Burt County, Nebr., about 2 miles from the river, on south line of sec. 31, T. 21 N., R. 12 E., 1,210 feet east of southwest corner of section 31, by the side of winding road on edge of old lake or river bed	611 414	
$\frac{130}{2}$	On left bank, about 4½ miles south of the River Sioux, Iowa, 108 feet north of Sioux City and Pacific R. R. track, in angle formed by intersection of east-and-west and north-and-south roads, 300 feet N. 27° W. (mag.) from Joseph Krummel's house	607.081	
$\frac{131}{1}$	One-half mile south of the town of Newton, Burt County, Nebr., opposite River Sioux, Iowa, in the SW. corner of the NW. ¼, Sec. 12, T. 21 N., R. 11 E., on premises of W. B. Newton	616.772	
$\frac{131}{2}$	Is one mile east of $\frac{131}{1}$, on SE. ¼ sec. 12, T. 21 N., R. 11 E., 690 feet south of the northeast corner, on west side of road, on premises of M. Shafer	617.448	
$\frac{131}{3}$ River Sioux.	At River Sioux, Iowa, at west fence of right of way Sioux City and Pacific Railroad, 1,260 feet south of railroad depot	618.558	728.0
$\frac{132}{1}$	Near foot of bluff, 10 miles below Decatur, Nebr., 30 feet east of SW. corner of sec. 19, T. 22 N., R. 11 E., on premises of Bent. Gilbert	624.249	
$\frac{132}{2}$	On right bank, 4 miles east of $\frac{132}{1}$, three-fourths mile from the river, on east side of north-and-south section line road, between secs. 22 and 23, T. 22 N., R. 11 E., one-fourth mile north of southwest corner of section 23, on premises of Peter Mar	618.875	734.0
$\frac{132}{3}$	On left bank, 2,800 feet from the river bank, in NE. ¼ sec. 6, T. 81 N., R. 45 W., 715 feet southwest of the northeast corner of section, on west side of road, opposite barn of M. Marley	617.860	
$\frac{132}{4}$	About 4½ miles north of River Sioux, Iowa, at west right-of-way fence of Sioux City and Pacific Railroad, 608 feet north of south line of Monona County, Iowa	614.368	
$\frac{133}{1}$	Five miles south of Decatur, Nebr., on side of bluff, near the foot, 210 feet west of road running along the foothills, on north side of sec. 31, T. 23 N, R. 11 E., 40 feet east of northwest corner of section, on land of Stanton heirs, one-half mile north of Golden Spring post-office	689.334	

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{133}{1}$	On right bank, about 3 miles east of $\frac{133}{2}$, in dooryard of C. A. Sprague, one-fourth mile east of NW. corner sec. 34, T. 23 N., R. 11 E	626.217	739.0
$\frac{133}{2}$	On left bank, 1½ miles from river bank, in southeast angle formed by cross-roads, at NW. corner of NE. ¼ of SE. ¼ sec. 7, T. 82 N., R. 45 W. Land owned by Thorley heirs	624.662	
$\frac{133}{3}$	About 8 miles north of River Sioux, Iowa, 508 feet west of Sioux City and Pacific Railroad, 460 feet north of south line of the SE. ¼ sec. 9, T. 82 N., R. 45 W	623.716	
$\frac{134}{1}$	About 3½ miles south of Decatur, Nebr., 25 feet south of section line between secs. 13 and 24, T. 23 N., R. 10 E., and 1,485 feet west of northeast corner of section 24, on west side of road, at foot of bluff, on land owned by J. B. Walker	630.581	
$\frac{134}{2}$	On left bank, nearly east of Decatur, Nebr., 2 miles from the river, on east side of road, 498 feet north of the south ¼ post of sec. 7, T. 83 N., R. 45 W., in garden of Wm. Rice	631.526	
$\frac{134}{3}$ Onawa.	In town of Onawa, Iowa, in church yard of German Lutheran Church, at corner of Granite and Maple streets	634.310	
$\frac{135}{1}$ Decatur.	In town of Decatur, Nebr., in corner of W. S. Page's lot, on west side of Broadway, 62 feet south of Sixth street	649.451	749.0
$\frac{135}{2}$	On left bank, opposite Decatur, Nebr., in NE. ¼ sec. 4, T. 83 N., R. 46 W., on north side of road along the south side of the quarter, and one-fourth mile west of the southeast corner of said quarter	638.090	
$\frac{135}{3}$	About 2¼ miles easterly from $\frac{135}{2}$, on south side of road, 760 feet west of corner to secs. 25, 26, 35, 36, T. 84 N., R. 46 W., on premises of Oscar Tuttle	635.507	
$\frac{137}{1}$	About 6 miles north of Decatur, Nebr., at foot of Blackbird's Hill, 15 feet up from the point where the wagon road down the hill turns down the river; is about 100 feet south of a small spring brook	654.237	759.0
$\frac{137}{2}$	On left bank, opposite Blackbird's Hill, 2¼ miles from $\frac{137}{1}$, on east side of section line road, 990 feet north of the SW. corner of sec. 7, T. 84 N., R. 46 W., 490 feet south of G. H. Brooks' house	648.210	
$\frac{137}{3}$	Three miles east and nearly one mile north of $\frac{137}{2}$, on west side of section line road, 476 feet north of the SE. corner of sec. 4, T. 84 N., R. 46 W., on land owned by M. Crawford	644.723	
$\frac{138}{1}$ Omaha Mission.	At Omaha Mission, Nebr., near foot of bluff, on a small spur about 8 feet higher than the bottom land, 50 feet from road along foot of bluff, about 400 feet northeast from the mission house	661.977	767.7
$\frac{138}{2}$	On left bank, opposite Omaha Mission, 2 miles from $\frac{138}{1}$, on east side of section line road, 1,068 feet north of west ¼ post of sec. 22, T. 85 N., R. 47 W., in dooryard of George Nelson	653.454	
$\frac{138}{3}$	On continuation of line $\frac{138}{1}$ to $\frac{138}{2}$, 6 miles from $\frac{138}{2}$, at west right-of-way fence of Sioux City and Pacific Railroad, 2,410 feet south of the north line of sec. 9, T. 85 N., R. 46 W	649.327	
$\frac{139}{1}$	Near the south line of the Winnebago Reservation, Nebr., where it comes to the river, 35 feet back from the edge of the bluff, 360 feet north of a spring brook. Bench mark is about 50 feet higher than the bottom land	708.470	772.0
$\frac{139}{2}$	On the left bank, opposite $\frac{139}{1}$, on west side of north-and-south road, 1,670 feet south of the NE. corner of sec. 26, T. 86 N., R. 47 W	657.765	
$\frac{139}{3}$	Is 5,595 feet north of railroad depot at Sloan, Iowa, at west right-of-way fence of Sioux City and Pacific Railroad, 960 feet north of south line of sec. 19, T. 86 N., R. 46 W	656.092	
$\frac{140}{1}$	About 1 mile from the river, three-fourths of a mile north of south line of Dakota County, Nebr., at foot of bluff, in dooryard of Daniel Don, near the NE. corner of SW. ¼ of sec. 27, T. 27 N., R. 11 E	665.656	791.7
$\frac{140}{2}$	On left bank, about 1½ miles west of Salix, Iowa, on west side of north-and-south section line road, about 2,000 feet north of SE. corner of sec. 33, T. 87 N., R. 47 W., 1,100 feet north of A. T. Bigelow's house	664.755	
$\frac{140}{3}$	At west right-of-way fence of Sioux City and Pacific Railroad, 1,430 feet north of Salix, Iowa, railroad depot	663.702	
$\frac{141}{1}$ Omadi Creek.	One-fourth mile north of Omadi Creek, on township line between T. 27 and 28 N., in Nebraska, one-fourth mile west of SE. corner sec. 31, T. 28 N., R. 11 E., in corner of yard of George Wilkinson	677.772	
$\frac{141}{2}$	On left bank, 3½ miles east of $\frac{141}{1}$, at east side of section line road, 680 feet north of SW. corner of sec. 12, T. 87 N., R. 48 W., on premises of E. R. Allen	674.343	
$\frac{142}{1}$	About 2¼ miles west of Dakota City, Nebr., at east side of north-and-south road, 540 feet south of house of E. Bodendenders, in SW. ¼ sec. 6, T. 28 N., R. 11 E	682.932	

Descriptions and elevations of bench-marks on the Missouri River, etc.—Continued.

P. B. M.	Description.	Elevation.	Above the mouth.
		Feet.	*Miles.*
$\frac{142}{1}$ Dakota City.	In Dakota City, Nebr., in northeast corner of county court-house yard	680.020	796.5
$\frac{142}{2}$	In town of Sargent's Bluff, in dooryard of E. F. Berry, on lots 1 and 2 on Mulberry street	676.957	
$\frac{142}{1}=\frac{142}{2}$		680.020	796.5
$\frac{143}{2}$	In South Sioux City, Nebr., in dooryard of N. H. Emery, in northeast corner of lot 2, block 27, in Moon's addition	685.305	
$\frac{142}{3}$	In Sioux City, Iowa, in southwest corner of county court-house yard	692.846	802.8

Table showing elevations (referred to the St. Louis City directrix) of permanent bench-marks between Sioux City, Iowa, and Fort Leavenworth, Kans., derived from levels run in 1890; also showing differences in elevation of consecutive bench-marks.

A plus (+) difference denotes that the B. M. whose number stands opposite has a greater elevation than the one next preceding.

A minus (—) difference shows that the elevation of the B. M. whose number stands opposite has a less elevation than the one next preceding.

Blank spaces, where they occur in the table, indicate that no levels were run between the B. M. whose number stands opposite and the one next preceding.

Under the head of "first levels" is shown the difference in elevation as found by levels run in one direction. Under the head of "checks" is shown the difference as found by levels run in the opposite direction. The mean of the two elevations thus found is, as a rule, taken as the true difference of elevation between the points.

Number of bench-mark.	Difference in elevation, in feet.			Elevation in feet.
	By first level.	By check.	Mean.	
272 (195) 1881				(358.096)
$\frac{80}{1}$	− 2.434	− 2.440	− 2.437	355.659
$\frac{80}{2}$	− 4.174	− 4.170	− 4.172	351.487
$\frac{80}{3}$	+ 5.074	+ 5.083	+ 5.078	356.565
278 (189) 1881			+24.801	(381.366)
$\frac{81}{1}$	+ 6.484	+ 6.484	+ 6.484	387.850
$\frac{81}{2}$	−32.844	−32.701	−32.773	355.077
$\frac{81}{3}$	+ 9.254	+ 9.268	+ 9.261	364.338
283 (184) 1881			+ 6.040	(370.378)
$\frac{82}{1}$	− 2.912	− 2.909	− 2.911	367.467
$\frac{82}{2}$			+20.637	388.104
346 (121) 1881			+69.219	(457.323)
$\frac{97}{1}$	+13.723	+13.721	+13.722	471.045
$\frac{98}{2}$	−39.696	−39.737	−39.716	431.329
$\frac{97}{3}$	− 1.074	− 1.073	− 1.074	430.255
351 (116) 1881			+14.234	(444.489)
$\frac{98}{1}$	+21.327	+21.322	+21.325	465.814
$\frac{98}{2}$	−30.127	−30.134	−30.130	435.684
$\frac{98}{3}$	− 0.880	− 0.892	− 0.886	434.798
351 (116) 1881			+ 9.691	(444.489)
$\frac{99}{1}$	+ 1.323	+ 1.330	+ 1.326	445.815
$\frac{99}{2}$	− 2.861	− 2.871	− 2.866	442.949
$\frac{99}{3}$	+ 1.816	+ 1.809	+ 1.813	444.762
360 (107) 1881			+11.265	(456.027)
$\frac{100}{1}$	− 3.141	− 3.141	− 3.141	452.886
$\frac{100}{2}$			− 3.581	449.305
$\frac{100}{3}$	− 0.562	− 0.565	− 0.563	448.742
363 (104) 1881			+54.264	(503.006)
$\frac{101}{1}$	−10.189	−10.189	−10.189	492.817
$\frac{101}{2}$	−34.572	−34.586	−34.579	458.238
$\frac{101}{3}$	− 4.108	− 4.116	− 4.112	454.126
366 (101) 1881			+17.338	(471.464)
$\frac{102}{1}$	−10.218	−10.211	−10.214	461.250
$\frac{102}{2}$	− 4.051	− 4.056	− 4.053	457.197
$\frac{102}{3}$	+ 2.364	+ 2.368	+ 2.366	459.563
373 (94) 1881			+43.579	(503.142)
$\frac{103}{1}$	−37.668	−37.669	−37.668	465.474
$\frac{103}{2}$	− 1.850	− 1.849	− 1.849	463.625
$\frac{103}{3}$	− 0.827	− 0.830	− 0.828	462.797
375 (92) 1881			+16.331	(479.128)
$\frac{104}{1}$	− 1.920	− 1.920	− 1.920	477.208
$\frac{104}{2}$			− 8.706	468.502

Table showing elevations of permanent bench-marks, etc.—**Continued.**

Number of bench-mark.	Difference in elevation, in feet.			Elevation in feet.
	By first level.	By check.	Mean.	
382 (85) 1881			+16.206	(484.708)
$\frac{105}{1}$	− 1.882	− 1.883	− 1.883	482.825
$\frac{105}{2}$	−12.624	−12.633	−12.628	470.197
$\frac{105}{3}$	− 0.531	− 0.534	− 0.533	469.664
383 (84) 1881			−27.438	(497.102)
$\frac{106}{1}$	− 4.842	− 4.842	− 4.842	492.260
$\frac{106}{2}$	−18.884	−18.898	−18.891	473.369
$\frac{106}{3}$	+ 1.506	+ 1.499	+ 1.503	474.872
386 (81) 1881			+29.469	(504.341)
$\frac{107}{1}$	−19.032	−19.038	−19.035	485.306
$\frac{107}{2}$	− 1.305	− 1.303	− 1.304	484.002
388 (79) 1881			+ 7.084	(491.086)
$\frac{108}{1}$	+ 5.073	+ 5.078	+ 5.075	496.161
$\frac{108}{2}$	− 8.859	− 8.856	− 8.857	487.304
394 (73) 1881			+43.281	(530.585)
$\frac{109}{1}$	−34.128	−34.127	−34.127	496.458
$\frac{109}{2}$	+ 2.379	+ 2.382	+ 2.380	498.838
$\frac{109}{3}$	− 6.100	− 6.093	− 6.096	492.742
394 (73) 1881			+37.843	(530.585)
$\frac{110}{1}$	−30.402	−30.395	−30.399	500.186
$\frac{110}{2}$			− 7.163	493.023
$\frac{110}{3}$	− 1.655	− 1.660	− 1.657	491.366
Gauge B. M., Nebraska City, Neb.			+39.872	(531.238)
$\frac{111}{1}$	+ 0.842	+ 0.838	+ 0.840	532.078
$\frac{111}{2}$	−26.661	−26.663	−26.662	505.416
401 (66) 1881			+39.093	(544.509)
$\frac{112}{1}$	+48.183	+48.179	+48.181	592.690
$\frac{112}{2}$			−80.009	512.681
403 (64) 1881			+29.744	(542.425)
$\frac{113}{1}$	− 4.942	− 4.942	− 4.942	537.483
$\frac{113}{2}$	−21.730	−21.727	−21.729	515.754
$\frac{113}{3}$	+ 0.446	+ 0.440	+ 0.443	516.197
407 (60) 1881			+13.529	(529.726)
$\frac{114}{1}$	− 5.888	− 5.888	− 5.888	523.838
$\frac{114}{2}$	− 5.407	− 5.401	− 5.404	518.434
$\frac{114}{3}$	+ 0.144	+ 0.141	+ 0.142	518.576
410 (57) 1881			+16.296	(534.872)
$\frac{115}{1}$	+ 4.269	+ 4.271	+ 4.270	539.142
$\frac{115}{2}$	−12.643	−12.644	−12.643	526.499
413 (54) 1880			+10.404	(536.903)
$\frac{116}{1}$	+18.482	+18.481	+18.482	555.385
$\frac{116}{2}$	−23.301	−23.304	−23.303	532.082
$\frac{116}{3}$	− 0.437	− 0.449	− 0.443	531.639
416 (51) 1880			+20.315	(551.954)
$\frac{117}{1}$	−11.934	−11.934	−11.934	540.020
$\frac{117}{2}$	− 1.222	− 1.231	− 1.226	538.794
$\frac{117}{3}$	− 2.380	− 2.389	− 2.385	536.409
418 (49) 1880			+14.592	(551.001)
$\frac{118}{1}$	+22.392	+22.388	+22.390	573.391)
$\frac{118}{2}$			−33.611	539.780
424 (43) 1880			+33.619	(573.399)
$\frac{119}{1}$	−14.130	−14.131	−14.131	559.268
$\frac{119}{2}$	−11.060	−11.064	−11.062	548.206
$\frac{119}{3}$	+ 7.595	+ 7.595	+ 7.595	555.801
425 (42) 1880			+12.547	(568.348)
$\frac{120}{1}$	+21.823	+21.816	+21.820	590.168
428 (39) 1880			−21.884	(568.284)
$\frac{121}{1}$	+34.376	+34.362	+34.369	602.653
$\frac{121}{2}$	−25.501	−25.492	−25.497	577.156
$\frac{122}{1}$	− 7.700	− 7.641	− 7.671	569.485
$\frac{122}{2}$	− 7.309	− 7.352	− 7.331	562.154
$\frac{123}{1}$	+28.061	+28.092	+28.076	590.230
$\frac{123}{2}$	−19.373	−19.387	−19.380	570.850
$\frac{124}{1}$	+28.941	+28.949	+28.945	599.795
$\frac{124}{2}$	−29.571	−29.595	−29.583	570.212
$\frac{125}{1}$			+81.027	651.052
$\frac{126}{1}$	−47.919	−47.901	−47.910	603.142
$\frac{126}{2}$	−18.304	−18.356	−18.330	584.812
$\frac{127}{1}$	+78.972	+79.013	+78.992	663.804
$\frac{127}{2}$	−27.562	−27.570	−27.566	636.238
$\frac{127}{3}$	−47.294	−47.318	−47.405	588.833
$\frac{128}{1}$	+ 5.986	+ 6.015	+ 6.100	594.933
$\frac{128}{2}$	+ 4.943	+ 4.937	+ 4.940	599.873
$\frac{129}{1}$	− 1.584	− 1.582	− 1.583	598.290
$\frac{129}{2}$	+ 2.419	+ 2.447	+ 2.433	600.723
$\frac{129}{3}$	+ 2.191	+ 2.187	+ 2.189	602.912
$\frac{129}{4}$	− 2.656	− 2.692	− 2.674	600.238
$\frac{130}{1}$	+11.154	+11.199	+11.176	611.414

Table showing elevations of permanent bench-marks, etc.—Continued.

Number of bench-mark.	Difference in elevation, in feet. By first level.	By check.	Mean.	Elevation in feet.
130	− 4.309	− 4.358	− 4.333	607.081
131	+ 9.663	+ 9.719	+ 9.691	616.772
131	+ 0.673	+ 0.679	+ 0.676	617.448
131	+ 1.143	+ 1.077	+ 1.110	618.558
131	+ 5.687	+ 5.695	+ 5.691	624.249
132	− 5.370	− 5.377	− 5.374	618.875
132	− 1.015	− 1.014	− 1.015	617.860
132	− 3.501	− 3.483	− 3.492	614.368
133	+74.970	+74.963	+74.966	689.334
133	−63.118	−63.116	−63.117	626.217
133	− 1.555	− 1.555	− 1.555	624.662
133	− 0.948	− 0.944	− 0.946	623.716
134	+56.863	+56.866	+56.865	680.581
134	−49.052	−49.058	−49.055	631.526
134	+ 2.793	+ 2.776	+ 2.784	634.310
135	+15.139	+15.143	+15.141	649.451
135	−11.363	−11.359	−11.361	638.040
135	− 2.578	− 2.588	− 2.583	635.507
137	+18.735	+18.726	+18.730	654.237
137	− 6.022	− 6.032	− 6.027	648.210
137	− 3.486	− 3.489	− 3.487	644.723
138	+17.259	+17.249	+17.254	661.977
138	− 8.526	− 8.520	− 8.523	653.454
138	− 4.120	− 4.134	− 4.127	649.327
139	+59.146	+59.139	+59.143	708.470
139	−50.712	−50.689	−50.705	657.765
139	− 1.665	− 1.681	− 1.673	656.092
140	+ 9.558	+ 9.570	+ 9.564	665.656
140	− 0.905	− 0.897	− 0.901	664.755
140	− 1.046	− 1.061	− 1.053	663.702
141	+14.081	+14.059	+14.070	677.772
141	−3.421	−3.436	−3.429	674.343
142	+8.571	+8.607	+8.589	682.932
142	−2.911	−2.914	−2.912	680.020
142	−3.056	−3.071	−3.063	676.957
143	+3.056	+3.071	+3.063	680.020
143	+5.236	+5.335	+5.285	685.305
466 "A" a, 1880			+7.419	(692.724)
B. M. "A," 1880			+5.093	(697.817)
143	−4.971	−4.971	−4.971	592.846

APPENDIX A 9.

ANNUAL REPORT OF MR. A. H. BLAISDELL, ASSISTANT ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
St. Louis, Mo., June 30, 1891.

SIR: I have the honor to submit the following report on the water gauges maintained by the Missouri River Commission, and the office work incidental thereto, for the fiscal year ending June 30, 1891.

The following table gives in a condensed form the location of the gauges, their character, distances above the mouth, and the length of time they were maintained during the year.

Location of gauge.	Character of gauge.	Distance above mouth in 1879.	Time maintained during year.	Remarks.
		Miles.	*Months.*	
St. Charles, Mo	Bridge, cable	25.1	12	
Hermann, Mo	Shore, inclined	101.1	1 18/30	Readings commenced May 12, 1891.
Cole Creek, Mo	....do	104.7	1 11/30	Established May 19, 1891.
Jefferson City, Mo	Shore, inclined and vertical.	145.8	12	
Boonville, Mo	Bridge, cable	197.5	12	
Glasgow, Mo	....do	226.5	12	
De Witt, Mo	Shore, inclined	262.5	12	
Waverly, Mo	....do	297.4	12	
Lexington, Mo	....do	318.7	12	
Sibley, Mo	Bridge, cable	347.6	12	

Location of gauge.	Character of gauge.	Distance above mouth in 1879.	Time maintained during year.	Remarks.
		Miles.	*Months.*	
Randolph, Mo	Bridge, cable	382.3	$7\frac{6}{30}$	Discontinued Feb. 6, 1891.
Kansas City, Mo	....do	386.3	12	
Fort Leavenworth Bridge, Kans.	....do	418.9	12	
Atchison, Kans	....do	445.8	12	
St. Joseph, Mo	....do	479.5	12	
St. Joseph pump-house, Mo	Shore, cable	489.7	$7\frac{14}{30}$	Discontinued Feb. 14, 1891.
White Cloud, Kans	Shore, vertical	530.8	7	Discontinued Jan. 31, 1891.
Rulo, Nebr	Bridge, cable	542.1	12	
Brownville, Nebr	Shore, vertical	579.9	$5\frac{18}{30}$	
Do	Shore, cable	579.9	$6\frac{17}{30}$	
Nebraska City, Nebr	Bridge, cable	609.0	12	
Plattsmouth Bridge, Nebr	....do	638.3	12	
Omaha, Nebr	....do	667.8	12	
Blair, Nebr	....do	700.6	12	
Sioux City, Iowa	....do	800.9	12	
Pierre, S. Dak	Shore, vertical	1,176.0	11	
Bismarck, N. Dak	Bridge, cable	1,426.0	12	Distances given above Pierre are approximate.
Fort Buford, N. Dak	Shore, cable	1,698.0	$10\frac{18}{30}$	
Fort Benton, Mont	Bridge, cable	2,243.0	$10\frac{12}{30}$	

Three of the gauges were discontinued in consequence of being in close proximity to other more important, better-located, or longer established gauges, but not until the slope at various water stages had been well determined between them and the nearest gauge.

One new gauge was established at Cole Creek, 3.6 miles above Hermann, Mo., in May, 1891.

The Commission has never maintained a gauge at Hermann, but has made use of the daily records of the Signal Service gauge; this gauge is now so locked in by bars from the main river channel that its records even at moderately high stages are not reliable for slope measurement.

A gauge occupying the same position as the Signal Service gauge has been maintained by the Commission since the Cole Creek gauge was established, and will continue to be read till the present high water subsides.

All the gauges as far up as Sioux City are graduated to read elevations above the St. Louis directrix; those above Sioux City are graduated from local zeros or are referred to sea levels obtained from railroad profiles carried over from points on the Lakes.

The Commission's gauges are read twice daily, at 6 a. m. and 6 p. m. The observers send in, by postal cards, weekly reports; these are plotted on a hydrograph sheet as soon as received, which is carefully studied and compared at each station, and, if any errors are discovered they are at once rectified by correspondence and investigation. The records are then copied on a yearly card for permanent preservation; the daily mean is obtained, and it also is copied on a sheet for the printer's use.

The observer also keeps a record book, which is returned to the office at the end of the year.

Additional cards, giving the names and loads of passing steamers, notes of river phenomena, meteorological data, etc., are also sent in weekly by the observers.

The gauges in use on all the bridges as far up as Sioux City are what have been called standard wire-cable gauges. These give a much more accurate measurement of the elevation of water surface than any shore gauge can give, as they are placed directly over the channel of the river, and measure a height unaffected by the shore or other close obstruction.

That they are affected by change in camber of the bridge, due to changes in temperature, is doubtless true, as is also that the cable may stretch to an appreciable amount, but the monthly inspection of each gauge made by the division engineer renders any cumulative error impossible.

Should frequent inspection of the cable gauge not be possible, an intelligent observer can readily mark off on his bridge the total length of his cable, and have permanent marks for testing or replacing the gauge when necessary.

A drawing showing the general arrangement of the standard cable gauge is herewith presented.

The weight is usually a 16 to 20 pound cast-iron window weight; the cable is the best Swedish iron-wire sash cord, one-eighth inch diameter; the cast-iron sheave may be any pattern of a deeply grooved wire-rope sheave about 10 inches diameter, fastened

to the side of the guard rail of the bridge by an 8-inch lag screw, with washer inserted to permit the sheave to revolve easily; the gauge scale is preferably of white oak, graduated to feet and tenths, with graduations and numbers scored in.

The turnbuckle which carries the index is an improvement on the one formerly in use. It permits of an error in either direction of two-tenths to be taken up on the screw-threads, and by means of the metal washer between the nuts the latter can be locked after the gauge has been made correct.

The life of a cable gauge appears to depend entirely upon the care the observer gives the wire sash-cord, which should be protected from rust by frequent greasing.

Occasionally the weight is lost by accident, usually traced to the observer's carelessness, and a broken record or an approximate one, taken from a temporary gauge, results. This can best be prevented by having two sets of cables and weights constantly in the observer's possession, which is an inexpensive matter, or by having two complete gauges on each bridge.

The cable gauge as applied to a high bridge is shown on an accompanying drawing of a panel length, with sections, of the Blair Bridge. The cable is shown as drawn up when not in use, with the handle of the index thrown over a hook in the guard-rail, or padlocked thereto if necessary.

A cable gauge has been in very successful use on a shore gauge at Brownsville, Nebr., a drawing of which is also submitted. Mr. S. Waters Fox, division engineer, erected the gauge, making use of some abandoned piles, which had been left in an advantageous position. It replaced a vertical gauge which had always been troublesome to maintain. So long as it is not destroyed by ice or drift the gauge is a good one.

The gauge on the Bismarck Bridge is a modified form of cable gauge. The cable is used as a direct measure to find the distance from the water surface to the track stringer, the elevation of which is known by railroad levels. Another form is in use on the shore gauge at Fort Buford. It is essentially a beam stiffened by tie-rod, mounted on a truck, having one end overhanging. The truck moves on a wooden track at right angles to the bank, and when not in use the entire gauge is moved back out of harm's way. Visits of inspection to the upper-river gauges are expensive and infrequent. They have not received the attention given to those below.

A drawing is also presented of the recently constructed inclined wooden gauge at Cole Creek; it is made of cedar timber, 5 inches by 5 inches, with graduations and numbers marked with brass nails. There is no novelty about it, except perhaps that an advantageously located rock afforded a cheap and efficient means of securing the lower end of the gauge, bolts 1 inch diameter being leaded into the rock.

Comparisons of the readings of the gauges maintained by the Commission and those of the Signal Service, made more particularly the present year, show the following:

To obtain the Missouri River Commission, add to those of the Signal Service:

At Hermann, 71′.08.

At Boonville it has been found impossible to find any number which would equate the readings with any degree of constancy.

At Kansas City, 303′.35. This value has obtained very uniformly.

At Plattsmouth no equating value appears obtainable; the Commission gauge is on the bridge about 1 mile below the Signal Service shore gauge.

At Omaha, 545′.05. This value has obtained quite uniformly.

Since your last annual report the tabulation of mean daily stages of the river between the mouth and Sioux City, Iowa, for the years 1886, 1887, 1888, and 1889 has been printed in pamphlet form.

A revision of the standard low water, as printed in the report of 1889, has been made with the additional data at hand, but as the precise levels to be run next year will doubtless result in general small changes in the elevations of our bench-marks, its publication will be delayed until the results of that work are known.

Having a continuous series of gauge heights for a period of 12 years, 1879 to 1890, at several points on the river, embracing during that time two very high and two very low waters, and the remaining years quite evenly divided between high and low, it was decided by Colonel Suter to select three representative points, viz, St. Charles, Kansas City, and Sioux City, and deduce from the data at hand a mean Missouri River for that period in relation to gauge height and discharge.

The results are shown herewith both in tabulated and in graphical form.

The data at St. Charles refer to the bridge site; at Kansas City to the location of the Hannibal and St. Joseph Railroad bridge; and at Sioux City to the mouth of Perry Creek, the site of the original gauge.

The figures for discharge were deduced by Mr. James A. Seddon, assistant engineer, who fully describes in his report the methods he used.

Tables accompanying this report are as follows:

Mean daily stage of Missouri River for a period of 12 years, 1879–1890, at St. Charles; the same at Kansas City; the same at Sioux City. Mean monthly stage of Missouri

River for a period of 12 years, 1879–1890, showing the annual means at St. Charles, Kansas City, and Sioux City. Mean daily discharge of Missouri River for a period of 12 years, 1879–1890, expressed in thousands cubic feet per second at St. Charles; the same at Kansas City; the same at Sioux City. Mean monthly discharge of Missouri River for a period of 12 years, 1879–1890, expressed in thousands of cubic feet per second, showing also annual means, at St. Charles, Kansas City, and Sioux City. Total annual discharge of Missouri River for a period of 12 years, 1879–1890, expressed in cubic miles, at St. Charles, Kansas City, and Sioux City.

The drawings accompanying this report comprise three sheets illustrative of the gauges, and six sheets platted from the data in the tables, showing mean gauge, heights, and discharges, which need no explanation other than that contained in Mr. Seddon's report on the discharge hydrographs.

Very respectfully, your obedient servant,

A. H. BLAISDELL,
Assistant Engineer.

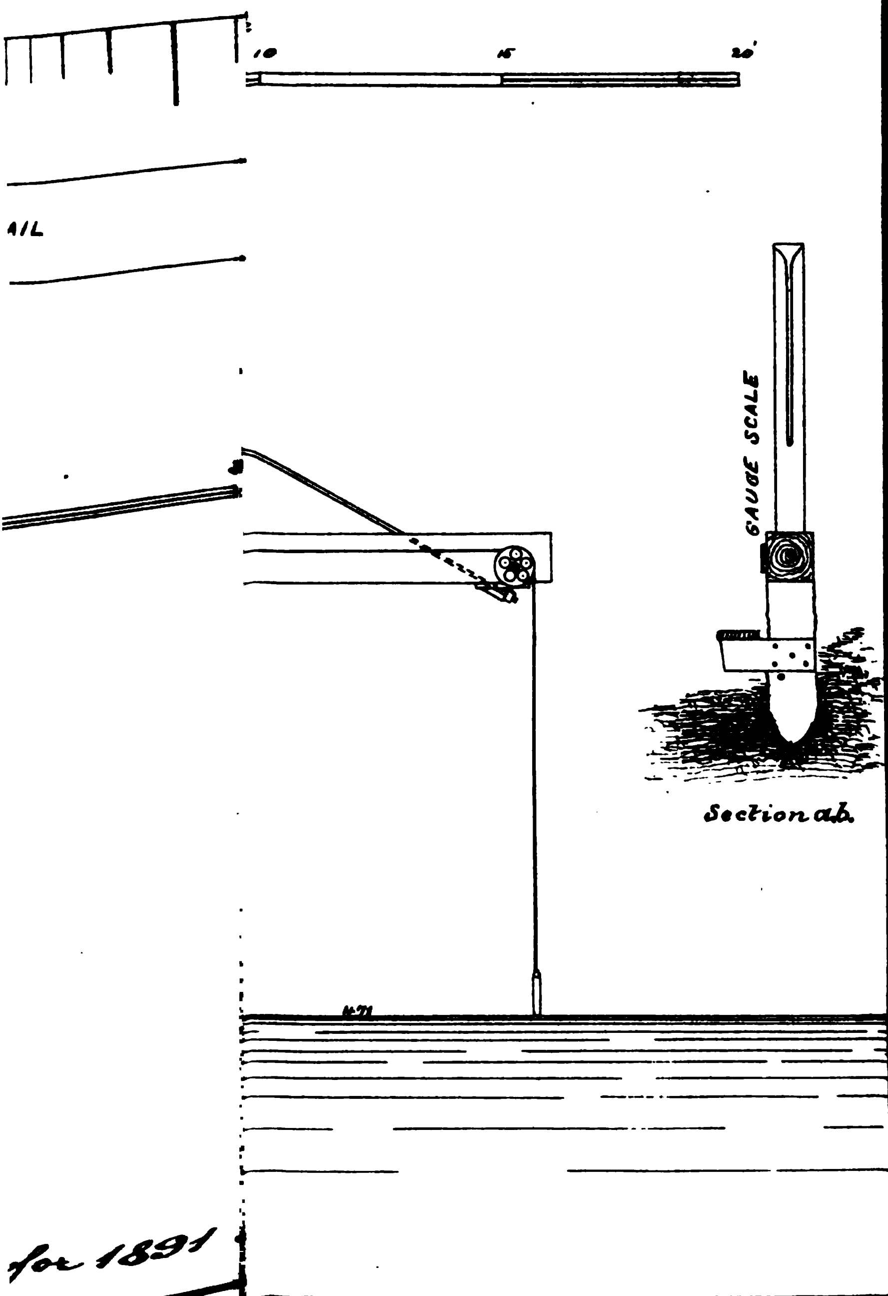
First Lieut. J. C. SANFORD,
Corps of Engineers, U. S. A.

Mean daily stage of Missouri River for a period of 12 years, 1879–1890.

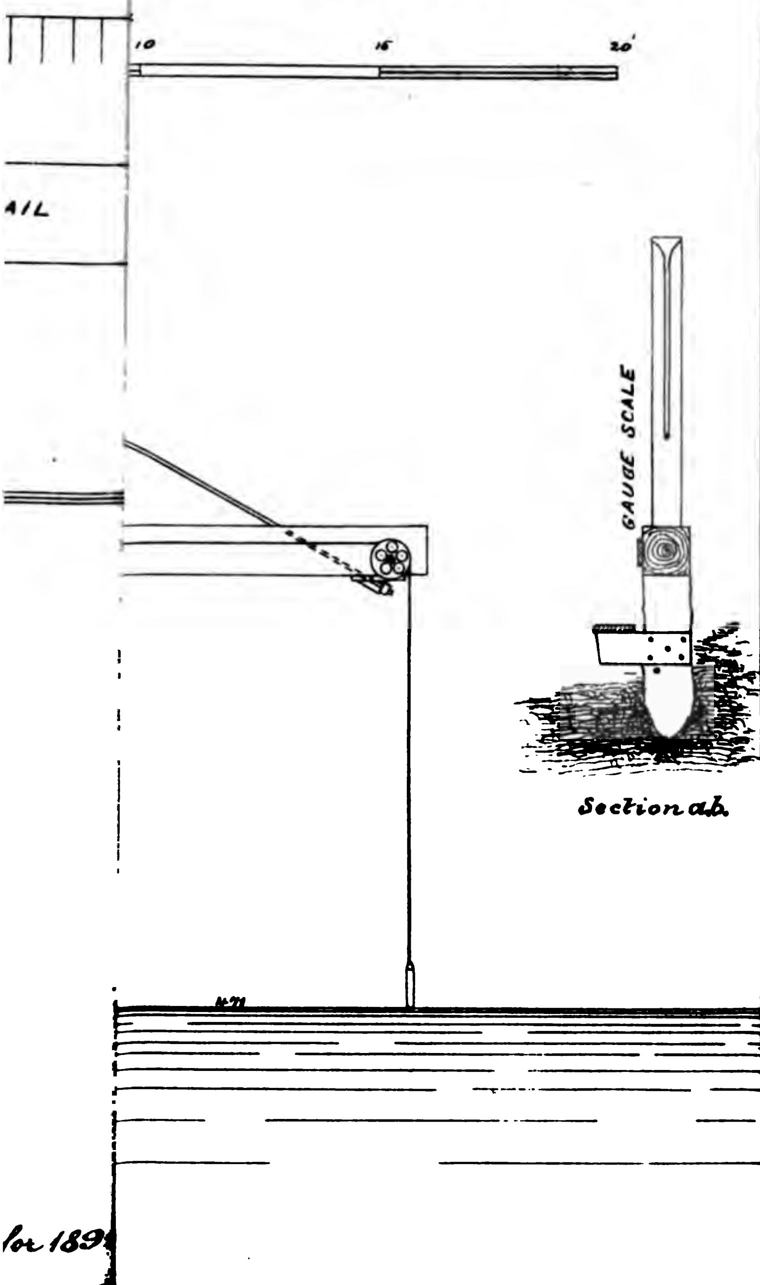
ST. CHARLES.

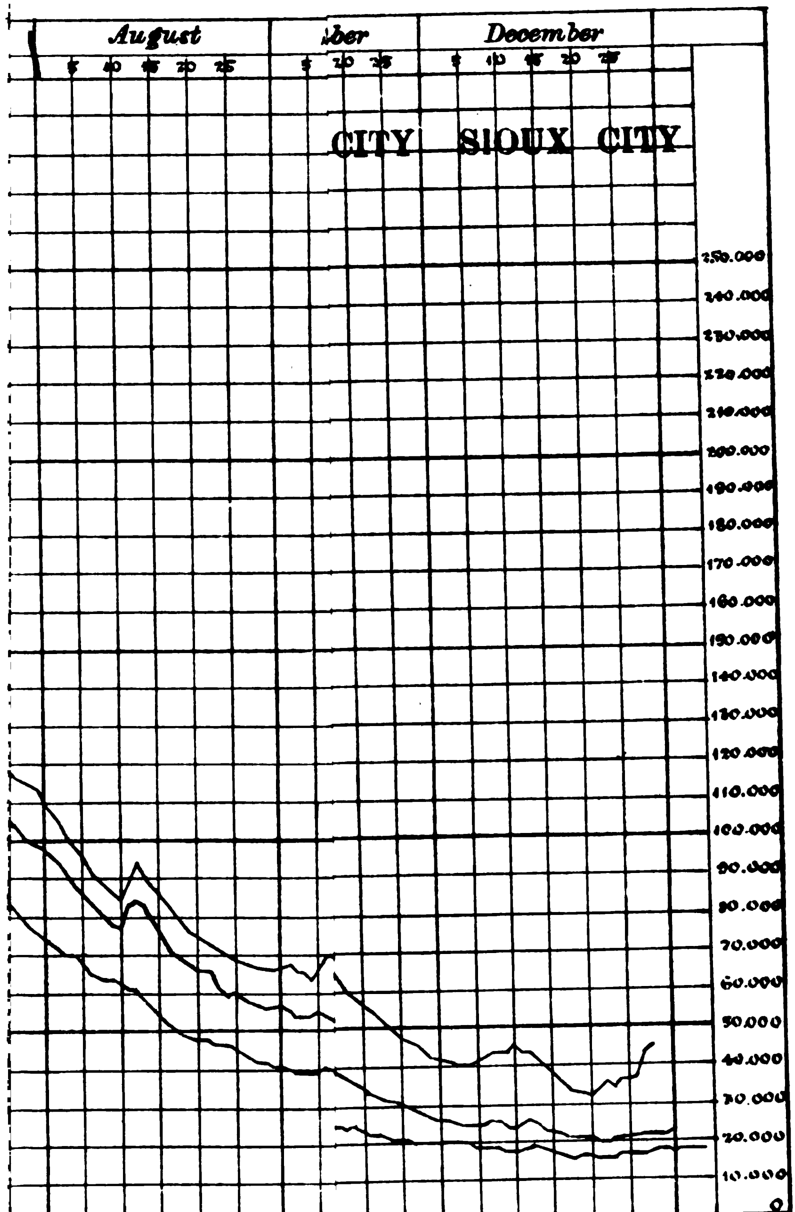
Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.6	9.1	13.0	15.6	16.0	16.7	20.3	15.1	11.4	10.2	9.5	8.9
2	8.6	9.4	12.8	15.6	16.0	16.6	20.2	15.0	11.4	10.4	9.5	8.8
3	8.6	9.6	12.7	15.8	15.7	16.7	20.1	14.8	11.4	10.4	9.5	8.7
4	8.5	10.0	12.7	15.9	15.7	16.7	19.9	14.7	11.4	10.2	9.4	8.6
5	8.5	10.4	12.7	15.8	15.7	16.7	19.6	14.6	11.3	9.9	9.3	8.5
6	8.6	10.5	12.9	15.4	15.7	16.6	19.3	14.3	11.2	9.8	9.3	8.5
7	8.9	10.5	12.9	15.4	15.5	16.6	19.2	14.2	11.0	9.8	9.2	8.5
8	9.4	10.6	12.6	15.7	15.3	16.6	19.1	14.1	11.2	9.7	9.2	8.5
9	9.2	11.1	12.3	15.8	15.0	16.8	18.9	13.9	11.4	9.7	9.3	8.6
10	9.0	11.6	12.3	16.3	15.1	17.2	18.7	13.7	11.3	9.8	9.6	8.7
11	9.2	11.6	12.5	16.0	15.1	17.2	18.4	13.5	11.2	9.8	9.7	8.7
12	9.5	11.4	12.8	16.7	15.1	17.2	18.1	13.3	11.1	9.9	9.8	8.6
13	9.8	11.5	13.1	16.6	15.0	17.6	17.9	13.2	11.0	9.9	10.0	8.8
14	9.8	12.0	13.2	16.5	14.9	17.8	17.8	13.5	11.2	9.8	10.2	8.7
15	9.8	12.1	13.5	16.4	14.8	18.0	17.9	13.8	11.0	9.6	10.4	8.7
16	9.8	12.3	13.7	16.2	14.9	18.2	18.1	13.6	10.8	9.3	10.6	8.4
17	9.8	12.5	13.8	16.0	14.9	18.6	18.0	13.4	11.2	9.3	10.6	8.2
18	9.8	12.6	13.9	15.8	15.1	19.0	17.8	13.2	11.2	9.4	10.6	8.0
19	9.8	12.4	14.2	15.8	15.3	19.2	17.4	13.1	10.9	9.5	10.8	7.8
20	9.7	12.8	14.3	16.0	15.5	19.5	17.2	12.8	10.7	9.8	10.6	7.6
21	9.5	13.1	14.3	16.0	15.7	19.9	17.0	12.6	10.5	9.9	10.5	7.5
22	9.4	12.9	14.5	16.2	15.6	20.1	16.7	12.4	10.3	9.9	10.4	7.4
23	9.2	12.8	14.6	16.9	15.4	20.2	16.4	12.3	10.1	10.0	10.2	7.3
24	9.0	12.9	14.4	17.2	15.2	20.3	16.2	12.2	9.9	10.2	10.1	7.5
25	9.0	13.0	14.4	17.0	15.3	20.3	16.1	12.0	9.7	10.1	9.9	7.6
26	9.1	13.2	14.6	16.7	15.4	20.2	16.1	11.9	9.7	9.9	9.7	7.4
27	9.1	13.2	14.7	16.6	15.3	20.4	16.0	11.8	9.8	9.8	9.5	7.5
28	9.0	13.1	14.8	16.5	15.8	20.6	15.6	11.7	9.8	9.6	9.3	7.5
29	9.0	12.2	14.8	16.3	16.3	20.6	15.4	11.6	10.0	9.5	9.2	7.8
30	9.0	....	15.1	16.1	16.8	20.5	15.3	11.5	10.0	9.5	9.1	8.3
31	9.2	....	15.5	....	16.9	....	15.2	11.4	....	9.5	....	8.6
Means	9.2	11.7	13.6	16.2	15.5	18.4	17.7	13.2	10.8	9.8	9.8	8.2

at Brownville, Neb.



at Brownville, Neb.

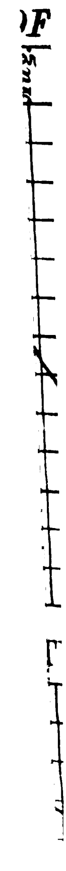




D OF 12 YEARS.

To accompa Blaisdell, Asst. Eng'r.

Eng 91



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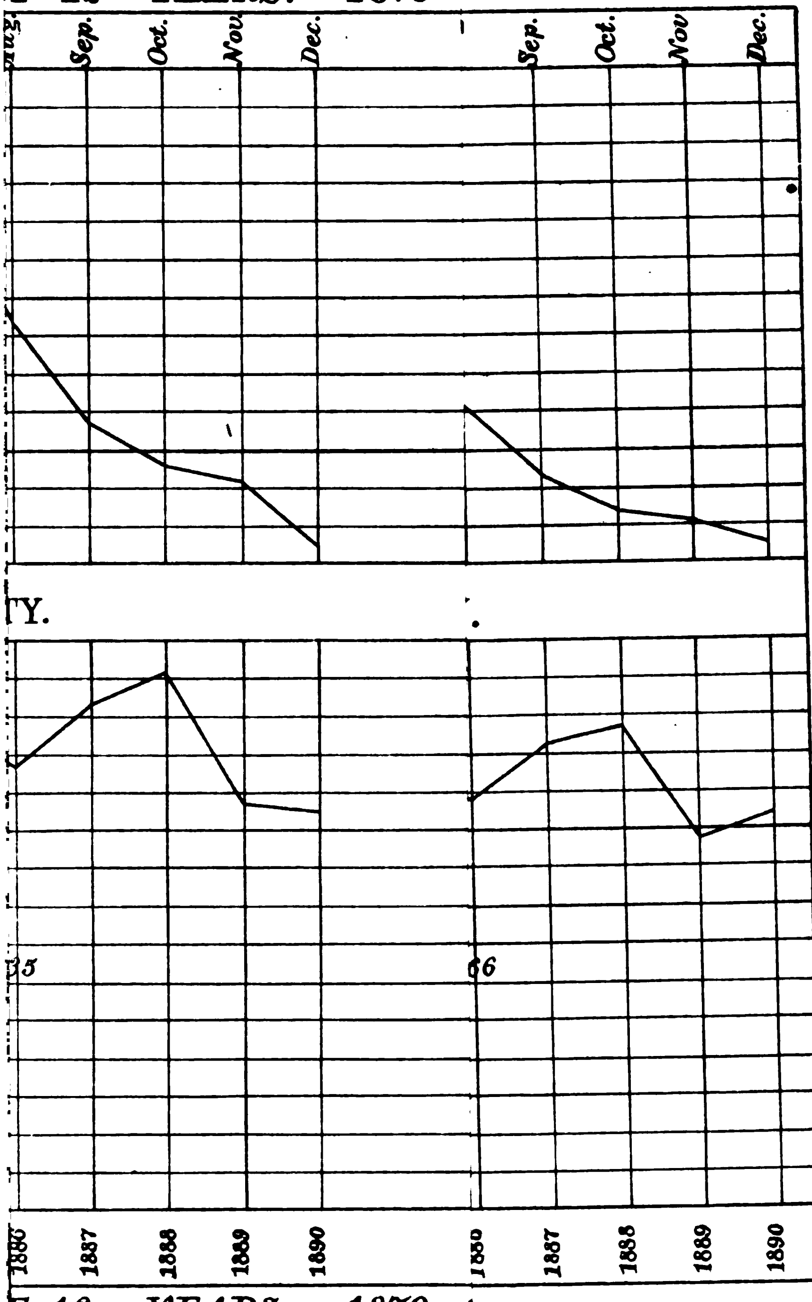

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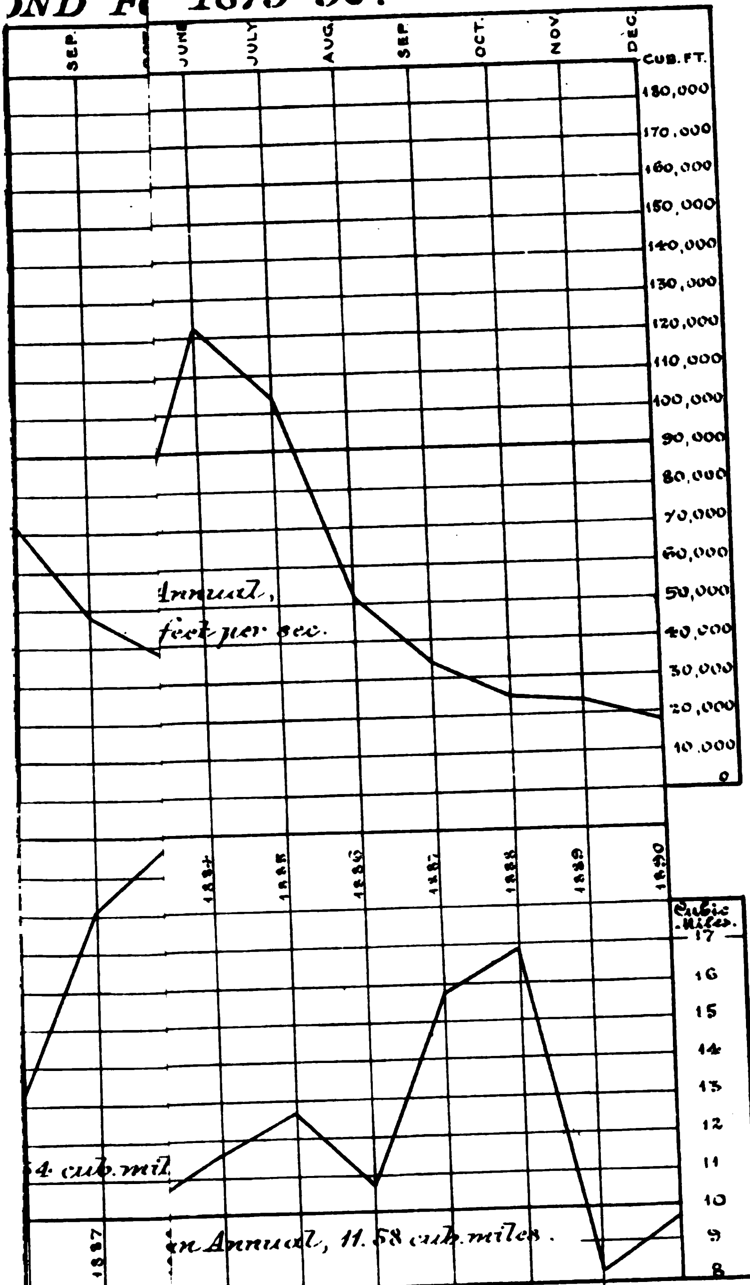

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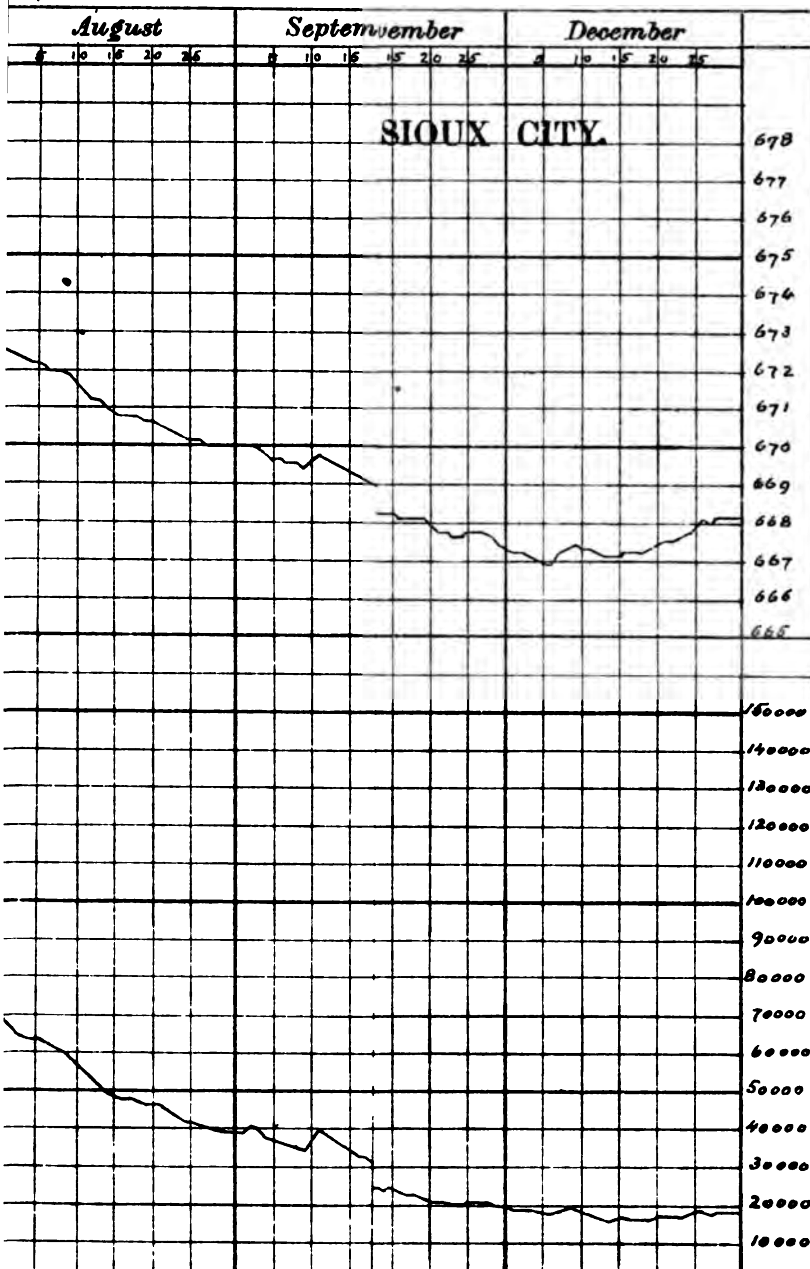
port for 1891, of A. H. Blaisdell, Asst Eng'r



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accompany annual repodell, Asst. Eng'r.

Eng 91

Mean monthly stage of Missouri River for a period of 12 years, 1879–1890.

ST. CHARLES.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean.
1879	7.3	7.6	8.2	14.0	12.6	17.9	19.2	13.2	8.5	7.0	9.4	8.7	11.18
1880	9.5	8.2	9.1	13.2	10.5	15.3	18.9	13.5	12.7	8.8	6.7	4.7	10.92
1881	7.2	12.3	17.7	22.3	20.7	18.3	16.5	10.7	8.4	13.9	13.7	10.8	14.40
1882	8.6	11.9	13.5	14.7	16.0	19.1	20.2	12.1	7.6	7.1	8.3	6.1	12.19
1883	6.7	14.9	14.0	13.7	15.6	24.7	21.0	14.3	9.1	9.5	11.0	7.7	13.52
1884	7.7	13.3	10.9	19.0	17.3	18.7	18.7	14.8	12.8	14.8	11.4	10.9	14.15
1885	13.0	13.0	16.7	17.8	17.4	21.0	18.9	14.7	16.1	10.1	10.3	7.9	14.70
1886	9.3	14.0	15.5	16.9	17.0	16.1	14.0	11.3	9.0	7.9	7.5	6.1	12.05
1887	7.9	11.1	14.6	16.8	14.1	17.5	17.4	12.7	12.7	10.5	9.1	8.4	12.73
1888	9.2	13.0	15.3	18.4	17.7	20.0	20.1	15.9	11.4	9.8	10.1	9.4	14.15
1889	11.7	10.3	14.8	13.7	14.3	16.9	14.3	13.6	10.7	8.6	11.0	8.9	12.40
1890	12.4	12.4	11.8	14.2	12.6	15.6	14.4	12.0	10.4	10.2	9.0	8.0	11.92
Means	9.2	11.8	13.6	16.2	15.5	18.4	17.8	13.2	10.8	9.8	9.8	8.2	12.85

KANSAS CITY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean.
1879	309.9	308.9	309.9	315.0	313.9	318.6	318.8	313.6	309.8	308.6	310.1	308.8	312.16
1880	308.7	308.3	308.8	312.3	311.0	315.7	318.9	314.2	312.7	310.4	307.9	306.7	311.30
1881	308.7	310.0	316.1	324.5	320.2	320.2	317.2	312.1	310.4	310.8	310.8	308.7	314.14
1882	307.0	307.3	310.1	313.6	314.1	317.8	319.0	312.6	308.6	308.4	308.0	305.5	311.09
1883	310.2	310.7	312.9	314.4	316.4	323.4	320.8	314.4	309.9	309.6	309.4	306.6	312.22
1884	307.7	308.9	312.2	318.2	315.7	320.0	318.6	313.8	312.1	311.7	309.5	307.1	312.96
1885	308.9	310.8	315.1	314.3	314.5	319.9	318.4	314.6	312.4	309.2	309.4	308.6	313.01
1886	308.7	311.7	315.0	315.5	314.9	317.2	314.2	311.8	309.2	308.2	307.9	306.3	311.72
1887	310.5	308.1	315.5	316.6	314.3	319.8	318.4	313.7	313.9	311.5	310.3	307.7	313.36
1888	310.9	312.8	314.2	319.4	318.3	319.8	319.6	314.9	311.2	309.7	309.7	308.4	314.07
1889	307.9	309.8	311.6	311.9	312.0	313.7	315.2	313.4	309.1	308.6	308.4	307.3	310.74
1890	306.6	309.2	310.2	311.6	310.9	317.3	315.3	311.4	309.5	308.8	308.6	307.4	310.56
Means	308.8	309.7	312.6	315.6	314.6	318.6	317.8	313.4	310.7	309.6	309.2	307.5	312.35

SIOUX CITY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean.
1879	667.1	668.0	669.1	673.4	672.5	676.5	675.1	670.5	668.1	667.4	667.5	666.5	670.14
1880	666.9	667.6	666.5	671.0	670.1	674.4	676.3	672.1	670.0	668.5	668.5	667.8	669.97
1881	668.3	669.0	674.0	680.6	673.0	675.1	672.1	669.8	668.7	668.2	667.2	666.3	671.02
1882	667.8	667.5	666.9	669.7	670.5	674.1	673.7	669.9	667.6	667.8	666.5	665.2	668.92
1883	666.6	666.5	670.4	670.9	672.3	674.5	674.5	669.9	667.8	666.9	666.4	664.7	669.28
1884	668.9	668.1	671.9	673.2	671.3	676.4	674.5	670.7	668.9	668.9	668.6	669.0	670.57
1885	670.1	671.0	673.5	672.4	671.7	675.8	674.7	671.8	670.2	669.3	669.1	669.3	671.58
1886	670.0	670.1	672.9	671.5	671.1	674.9	673.4	671.0	669.3	668.3	669.0	668.8	670.46
1887	669.7	669.8	674.8	672.9	672.5	677.5	676.1	672.4	672.4	670.1	669.8	670.2	672.35
1888	672.0	672.3	676.2	676.5	674.5	677.0	676.4	673.0	670.4	669.1	668.7	666.9	672.75
1889	669.2	670.5	670.9	670.4	670.2	672.4	672.7	670.2	668.5	667.7	667.4	667.1	669.76
1890	668.4	669.6	670.0	670.9	671.0	674.7	674.2	671.5	669.4	668.5	668.5	668.5	671.43
Means	668.7	669.2	671.4	672.8	671.7	675.3	674.5	671.1	669.3	668.4	668.1	667.5	670.66

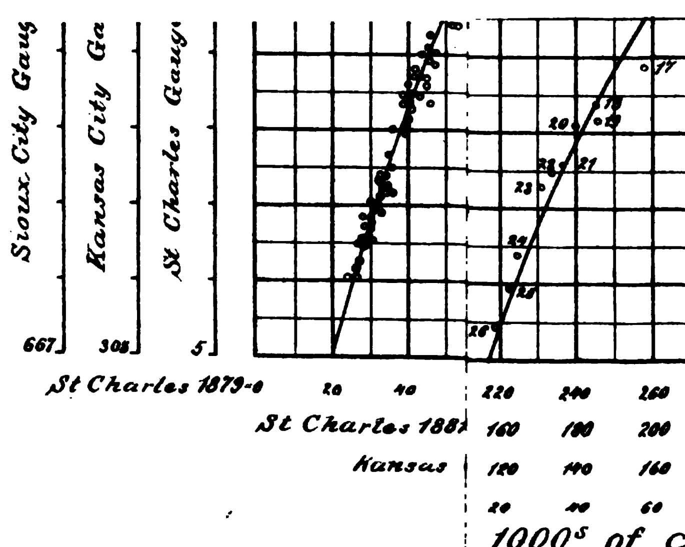
Mean daily discharge of Missouri River for a period of 12 years, 1879–1890, expressed in thousands cubic feet per second.

ST. CHARLES.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1......	45.5	46.5	84.5	126.5	141.5	147.0	230.0	115.0	66.5	58.5	49.0	44.5
2......	46.0	48.0	81.5	125.5	148.0	145.5	229.5	114.0	66.5	60.5	48.5	43.0
3......	45.5	50.5	80.0	126.0	149.5	145.5	225.0	110.0	67.5	59.0	49.0	42.5
4......	44.0	54.5	80.5	128.5	151.0	144.0	217.0	107.0	67.5	57.0	48.5	42.0
5......	43.5	60.0	81.0	127.5	153.0	143.0	209.0	105.0	66.0	54.0	47.5	41.0
6......	45.0	61.0	83.5	121.5	149.0	141.0	200.5	101.0	65.5	52.5	47.5	41.0
7......	47.0	61,0	82.0	121.0	141.0	140.5	195.0	99.0	64.0	52.0	46.0	41.0
8......	50.5	61.0	79.5	126.5	130.0	141.5	191.5	96.5	67.0	52.0	45.5	42.0
9......	49.0	67.0	76.0	131.0	121.0	144.0	188.0	92.5	70.0	51.5	47.0	43.0
10......	48.5	72.5	76.0	138.5	119.5	151.0	183.5	90.0	69.5	52.0	50.0	44.0
11......	49.5	70.5	78.0	145.0	118.5	151.5	178.0	88.5	68.0	53.0	51.0	44.0
12......	51.5	69.5	82.0	147.0	119.5	152.0	170.0	86.0	67.0	53.5	52.0	44,5
13......	55.5	72.0	85.5	146.0	120.0	161.0	166.0	85.5	65.5	54.0	53.5	45.5
14......	55.0	72.0	88.0	145.0	117.0	164.5	164.5	90.0	69.0	53.0	55.5	44.0
15......	55.0	75.5	93.5	142.0	114.5	174.0	166.5	95.0	67.0	50.5	57.5	44.0
16......	53.5	77.5	96.5	139.0	114.5	182.5	170.0	91.5	64.5	48.0	59.0	42.0
17......	53.5	80.5	96.5	135.5	114.5	189.0	168.5	88.5	69.0	48.0	60.0	40.0
18......	53.5	83.0	100.5	129.0	116.0	199.0	162.0	86.5	68.0	49.0	60.5	38.5
19......	52.5	80.0	103.0	128.0	120.5	204.5	156.0	84.0	65.0	50.0	65.5	36.5
20......	51.0	85.0	104.0	129.0	122.5	210.0	148.5	81.5	62.0	52.0	63.0	34.5
21......	49.5	92.5	104.0	129.0	124.5	221.0	145.0	79.0	60.0	53.5	60.0	33.5
22......	48.0	86.5	105.5	133.5	125.0	227.0	140.5	77.0	58.0	53.5	58.5	33.0
23......	47.0	84.0	107.0	148.0	121.0	231.5	135.5	75.5	55.5	54.5	56.5	32.5
24......	44.5	84.0	103.5	155.0	118.0	234.0	132.0	74.0	53.5	56.5	55.0	34.5
25......	44.5	85.0	104.5	151.5	118.5	234.0	130.5	72.5	51.5	56.0	53.5	35.5
26......	45.0	87.0	110.5	147.0	121.0	229.5	130.5	71.5	53.0	54.5	52.0	34.5
27......	45.5	86.5	116.0	146.0	120.5	233.0	129.0	70.0	53.0	52.5	50.0	35.5
28......	44.5	84.5	117.5	145.5	129.0	237.5	123.0	69.0	54.0	50.5	48.0	35.5
29......	44.5	....	116.0	143.5	139.0	237.0	120.0	68.0	56.0	49.5	47.0	37.5
30......	44.5	....	119.0	140.5	150.5	233.5	117.5	67.5	56.5	49.5	46.0	43.0
31......	46.0	....	124.0	....	152.0	....	116.0	67.0	....	49.0	....	45.0
Means.	48.3	72.8	95.5	136.6	129.0	185.0	165.8	87.0	62.9	52.9	52.7	39.9

KANSAS CITY.

1......	24.5	36.0	43.5	107.0	118.0	112.5	192.0	96.0	55.5	38.0	35.0	26.0
2......	24.5	35.5	44.5	103.0	115.0	113.0	192.0	94.5	53.5	38.0	35.0	25.5
2......	24.5	33.5	47.0	96.5	107.5	111.0	190.0	91.5	54.0	38.0	35.0	25.0
4......	25.0	32.5	47.0	96.0	99.0	113.0	184.0	88.5	54.0	38.0	35.0	25.0
5......	24.5	37.0	46.5	101.0	89.5	117.5	177.0	86.0	55.0	37.5	35.0	25.0
6......	23.5	41.0	49.0	107.0	85.0	122.0	171.5	84.0	54.0	37.0	35.0	25.5
7......	24.0	42.0	49.0	119.5	81.5	123.0	168.5	82.5	52.5	37.0	35.0	26.0
8......	24.5	41.5	50.5	123.5	81.0	123.0	161.5	80.0	53.0	36.5	35.5	25.5
9......	25.5	39.5	51.0	123.5	80.5	128.5	156.0	78.5	52.0	36.5	36.0	24.0
10......	26.5	38.0	52.5	126.0	80.5	135.0	154.0	77.0	51.0	36.5	37.0	24.0
11......	27.0	36.0	55.0	126.0	81.0	143.5	152.5	83.0	49.0	36.0	37.5	25.5
12......	28.0	37.0	58.5	125.5	81.0	144.5	154.0	84.5	48.0	35.5	30.0	26.0
13......	29.5	37.5	61.0	125.0	81.5	148.0	153.5	83.5	48.0	37.0	40.5	25.0
14......	28.5	39.5	63.0	121.0	84.5	156.5	148.5	79.5	50.0	38.5	41.5	23.5
15......	28.5	43.5	68.5	115.5	86.5	162.5	143.5	75.5	50.5	38.5	40.0	22.5
16......	28.5	38.5	73.5	110.5	86.0	169.5	138.0	72.0	50.0	37.0	39.0	22.5
17......	29.0	38.5	75.0	112.5	87.5	173.5	135.0	70.0	48.5	38.5	38.5	21.5
18......	30.5	39.0	75.5	112.0	92.0	179.5	132.0	69.0	46.0	38.5	37.0	21.5
19......	31.0	38.5	79.0	109.5	93.5	184.5	126.5	67.0	45.5	38.5	36.0	21.5
20......	31.5	40.0	81.0	116.5	90.5	190.0	121.0	66.5	44.0	38.5	34.5	21.0
21......	32.5	42.0	82.0	116.5	90.0	189.0	117.5	66.0	43.0	37.5	33.0	20.5
22......	32.0	39.5	75.5	113.5	91.5	188.5	116.0	65.5	42.5	37.0	32.0	20.5
23......	32.5	39.5	75.0	110.0	92.5	186.0	113.5	61.5	41.5	36.0	31.5	21.0
24......	32.0	39.0	78.0	106.5	92.5	190.5	110.5	59.5	42.0	35.0	31.0	21.0
25......	32.0	40.0	86.0	104.0	94.5	192.0	110.0	60.0	40.0	35.0	30.5	21.5
26......	32.0	40.0	92.5	104.5	99.5	192.0	108.5	58.5	39.0	35.5	29.5	21.5
27......	31.5	40.0	99.0	107.0	100.5	198.0	105.0	57.5	38.5	35.5	29.0	22.0
28......	32.0	41.0	101.5	112.5	100.0	199.5	102.0	57.0	40.0	35.5	27.5	22.0
29......	35.0	....	107.5	118.0	100.0	199.0	99.5	56.0	39.5	35.5	26.5	22.0
30......	36.0	....	111.0	119.5	103.0	194.5	98.5	56.0	38.5	35.5	26.0	22.5
1......	36.5	....	109.0	....	111.0	....	98.0	56.5	....	35.5	....	23.5
Means.	29.1	39.1	70.6	113.0	92.8	150.3	140.0	78.0	47.3	36.9	34.5	23.2


Sioux City Gaug
Kansas City Ga
St Charles Gaug
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St Charles 1879-0
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Mean monthly discharge of Missouri River for a period of 12 years, etc.—Continued.

SIOUX CITY.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual means.
1879	16.0	21.4	31.7	88.8	68.3	141.9	111.4	44.5	22.4	17.7	18.4	13.2	49.6
1880	14.1	19.0	13.9	48.5	39.7	100.1	137.8	64.7	30.4	25.3	22.7	20.6	45.5
1881	23.3	29.1	103.2	305.1	76.0	110.7	64.0	37.3	27.1	23.0	17.9	11.4	69.0
1882	20.2	18.7	20.1	45.7	53.0	113.2	92.0	37.9	18.8	20.0	13.9	10.2	38.6
1883	12.9	12.5	49.6	67.1	88.7	126.3	122.5	38.4	19.8	14.7	12.7	8.5	47.8
1884	27.4	21.9	64.3	86.9	53.4	141.8	100.0	46.6	28.3	29.0	25.9	20.1	53.8
1885	35.6	49.5	76.6	66.6	57.0	127.1	102.6	60.2	41.1	32.3	31.3	22.3	58.6
1886	28.9	39.7	78.3	55.6	49.9	107.5	81.4	50.3	31.9	23.6	26.0	26.5	50.0
1887	35.0	36.1	119.5	75.3	68.4	168.0	132.0	67.4	68.8	39.6	36.8	30.9	73.2
1888	45.6	57.8	101.0	145.0	99.5	155.1	146.9	74.6	43.2	30.5	27.0	15.0	78.4
1889	33.0	43.0	49.5	43.0	40.0	67.2	70.4	41.2	25.1	19.6	18.0	15.0	38.8
1890	24.6	34.4	39.0	48.8	49.6	102.3	87.6	47.5	32.2	24.6	25.2	21.9	44.7
Means	25.5	32.0	62.2	89.7	62.0	121.8	104.0	50.9	33.2	25.0	22.9	18.0	54.0

NOTE.—Floods require 7 days to pass from Sioux City to St. Charles; hence these monthly means can not be directly compared at the different stations.

Total annual discharge of Missouri River for a period of 12 years, 1879–1890, expressed in cubic miles.

Year.	St. Charles.	Kansas City.	Sioux City.	Year.	St. Charles.	Kansas City.	Sioux City.
1879	15.44	14.13	10.63	1886	17.62	13.27	10.72
1880	14.41	12.46	9.75	1887	21.16	18.03	15.69
1881	26.60	22.29	14.79	1888	25.27	19.77	16.81
1882	16.44	11.38	8.27	1889	17.04	10.61	8.32
1883	23.71	18.39	10.25	1890	16.34	10.46	9.58
1884	23.28	17.06	11.53				
1885	24.44	16.23	12.56	Means	20.15	15.34	11.58

APPENDIX A 10.

ANNUAL REPORT OF MR. JAMES A. SEDDON, ASSISTANT ENGINEER, 1891.

OFFICE MISSOURI RIVER COMMISSION,
St. Louis, Mo., June 30, 1891.

SIR: I have the honor to submit the following report on the study of physical data for the fiscal year ending June 30, 1891.

The work has consisted in completing the first general study of the Missouri River discharge and gauge data, and in determining the mean discharges from 1879 to 1890 of the river at Sioux City, Kansas City, and St. Charles. Following this, a more careful analysis of the movement of floods, the permanency of gauge relations, and the cause of changes of plane was taken up. This study is still in progress.

STUDY OF THE MISSOURI RIVER DISCHARGE AND GAUGE DATA.

All the discharge data taken on the Missouri River have been published in the report of the Commission for the year ending June 30, 1887, and the gauge data to 1885, and again to 1889, in pamphlet form. The special object of this investigation was to determine the laws of the variation of discharge, with stage, by which the mean discharges from 1879 to 1890 could be computed at Sioux City, Kansas City, and St. Charles, to correspond with the mean gauge readings of the same period.

By reference to the above discharge data it will be seen that, excepting some low-stage observations, of no help in the investigation, all that was available was a very full series of observations at St. Charles in 1879, and a short series at Sioux City in the same year, a fair series at Atchison in 1882, with a scattering series at Nebraska City, and a very short series at Omaha the same year; also a fair falling-stage series at Kansas City in 1883. In addition to these observed discharges, use was made of a series deduced for St. Charles in 1881 by taking the difference between the St. Louis and the Grafton observations of that year.

The only study prior to this investigation of discharge on the Missouri River had been strictly local in its character, consisting in passing approximate mean curves through the various local series of observations; and it was known from other investigations that this method might lead to very large errors, especially where, as in certain places on the river, the number of the observations were few and the range on the gauge small.

The method here followed, therefore, consisted in first determining the relations that existed between the gauge readings from point to point, from Sioux City to St. Charles, or the lines of gauge relation; after which a standard discharge curve could be transferred from point to point by these lines.

In the determination of the gauge relations it was known from other investigations that by allowing a constant time interval, to be determined by trial, between two gauges, the readings at the lower point should plot as abscissas to the readings of the upper as ordinates, on a definite line, except where increments to the discharge from tributaries between the gauges caused the lower value to diverge from this line, or except where a phenomenon called "change of plane" occurred, which was due to a break in the normal variation of discharge to gauge at one or both points. This phenomenon of change of plane has been traced the most fully, and reported on, in the study of Lower Mississippi discharge and gauge data.

The gauge readings were therefore plotted as gauge relations, with various trial intervals, and in various combinations of reaches, such as Kansas City-St. Charles gauge relation; and, again, the combination, Kansas City-Boonville, Boonville-Hermann, and Hermann-St. Charles relations; the subdivision into short reaches making it easier to identify and allow for tributary increments and changes of plane, and furnishing additional methods of deducing the equivalents between points.

At the outset of the investigation the questions were open whether on the Missouri River the time interval was constant, and whether straight lines of constant inclination would satisfactorily express the gauge relations. It was already known that the absolute position of the lines, wherever studied, varied from time to time.

The plotting of the gauge readings showed that, while there might be some variation of the interval between different floods, such as a small change at times between the spring and the regular June flood, yet, for the determination of the lines of gauge relation, a constant interval of, approximately, 110 miles per day along the whole river might be satisfactorily used; also, that while special relations might show a local peculiarity at stages, notably, as an instance, an indication of engorgement at Glasgow at high water, yet the general relations between points might be satisfactorily expressed by straight lines of constant inclination. Further, the plotting showed that, during the periods subject to the effects of ice action, no definite gauge relations could be said to exist.

Finally, from the plotting of the gauge readings, very satisfactory relations were obtained for all the reaches, except the Omaha-Nebraska City and the Atchison-Kansas City reaches, the former having the Platte River and the latter the Kaw River entering as tributaries between the upper and the lower gauges; and the preliminary lines determined from the gauge readings for these reaches were revised and changed in a further study of the discharge data. With these exceptions the relations between gauge readings for equal volumes of discharge, or the relations between local discharge curves, from Sioux City to St. Charles, were determined from gauge readings alone.

In the following tabulation are given two points of the equivalent readings on the principal gauges for the most permanent position of the relation in the year 1879.

Points of equivalent gauge relations, 1879.

Sioux City.		Omaha.		Nebraska City.		Atchison.		Kansas City.		St. Charles.
680′.0	=	563′.0	=	506′.8	=	369′.85	=	322′.6	=	22′.2
666.7	=	551.0	=	496.0	=	356.20	=	305.8	=	3.9

It is seen that these points fix the straight line of the equivalent relation between any two of the gauges. Thus the volume of discharge at that time passing Sioux City with the stage 680′.0 on that gauge would pass St. Charles with the stage 22′.2, and the same holds for the stages 666′.7 and 3′.9, respectively, while any intermediate value of gauge at Sioux City would have its equivalent intermediate value at St. Charles in the simple ratio to the change at Sioux City.

As before stated, the lines representing equivalent gauge readings, wherever studied, have been found only constant in their inclinations, and shifting from time to

time to parallel positions, with corresponding shiftings in the positions of the discharge curves at the points. The relations on the Missouri River were found to be no exception to this rule, and variations from the 1879 positions of one or more feet may be found from year to year. Thus, on another year 680.'0 at Sioux City might correspond with 562'.0 at Omaha, in which case 666'.7 would correspond with 550'.0. Such a change would in no way affect the relation *in form* between the discharge curves at Sioux City and Omaha, but only their relative position on their respective gauges, and considerable changes of this character are known to occur.

In fact, by far the larger part of the evidence from which we conclude that there is a permanent normal law of variation of discharge with gauge at a locality rests on the permanent inclination of the gauge relations. For the same variations of volume passing the two points year after year, and causing rises and falls on the two gauges in the same constant ratio, leads us to the conclusion that the change in gauge at each point is a definite constant function of the change in volume there, with much greater force than the evidence of the scattering discharge data that have been collected.

In the above gauge relations, as also in all the following data of this report, the gauge elevations used are those of the 1886 reduction to the St. Louis directrix, or elevations without the +0'.3 added.

After the determination of the relations of the discharge curves from point to point, it was necessary to determine, as well as possible the actual curve of the variation of discharge with gauge at some one point, which might then be taken as a standard and transferred to any of the others through the equivalent gauge relations.

By far the most complete series of discharges taken on the river were those of St. Charles in 1879, and a mean curve had already been computed for them. It was also seen that this curve, when suitably shifted on the gauge scale, agreed very well with the series deduced for St. Charles in 1881, and on trial, transferring it to Kansas City, it showed so fairly the curvature of the 1883 observations at that point (fitting them by being put down 0'.6 on the gauge) that, without further revision, it was accepted as the standard curve for transfer from point to point.

The ordinates of this curve in its position for the principal plane of 1879 are given in the following tabulation:

Ordinates of the 1879 discharge curves.

General value of discharge.*	Values of gauge.		
	St. Charles.	Kansas City.	Sioux City.
	Feet.	*Feet.*	*Feet.*
8.4	1.0	303.14	664.59
9.6	2.0	304.06	665.32
12.0	3.0	304.97	666.05
15.5	4.0	305.89	666.77
20.0	5.0	306.81	667.50
25.4	6.0	307.73	668.23
31.6	7.0	308.65	668.95
38.4	8.0	309.56	669.68
46.0	9.0	310.48	670.41
54.3	10.0	311.40	671.14
63.3	11.0	312.32	671.86
73.1	12.0	313.24	672.59
83.8	13.0	314.15	673.32
95.5	14.0	315.07	674.04
108.4	15.0	315.99	674.77
122.7	16.0	316.91	675.50
138.5	17.0	317.83	676.22
156.1	18.0	318.74	676.95
175.8	19.0	319.66	677.68
197.8	20.0	320.58	678.40
222.6	21.0	321.50	679.13
250.4	22.0	322.42	679.86
281.6	23.0	323.33	680.59
316.7	24.0	324.25	681.31
356.2	25.0	325.17	682.04
400.4	26.0	326.09	682.77
449.9	27.0	327.01	683.49
505.3	28.0	327.92	684.22
567.0	29.0	328.84	684.95
635.8	30.0	329.76	685.67

* The unit taken for discharge is 1,000 cubic feet per second.

The above ordinates are those computed for the curve at St. Charles and deduced from the 1879 lines of equivalent gauge relations at Kansas City and Sioux City.

The accompanying plate gives the discharge data with the standard and transferred curves at St. Charles, Kansas City, and Sioux City. In plotting the St. Charles 1879 discharges, those of the sharp April rise were omitted, as they were not used in computing the mean curve. The agreement of this curve with the observations is well shown.

In the St. Charles 1881 deduced discharges, the values of discharge show much greater divergences from the mean curve of that year. This is altogether what would be expected, for they contain in their St. Charles values the combined errors of the observations at both Grafton and St. Louis; and it should also be remembered that an error which was only a small per cent of the larger St. Louis discharge, when carried up to St. Charles, might be a much larger per cent of the discharge there. These values show that the mean curve of 1881 at St. Charles has a decidedly lower position on the gauge than in 1879. It is taken, as an approximation, at 1 foot lower. But especially are they interesting in showing the continuation of the curve values to the high stages of that year.

This flood of 1881 was within the banks at St. Charles, and its variation of discharge with gauge is in striking contrast with the 1883 flood observations at Kansas City, where the river was out of the banks during the first four observation (Nos. 1 to 4), and where we see a most marked decrease from the normal variation of discharge; the highest observation, No. 2, being 116,000 cubic feet per second less than the curve value for that stage, while, after the river falls to within banks, the curve agrees very fairly with all the other observations.

In the Sioux City 1879 observations, beyond the change of plane suggested between Nos. 4 and 5, the curve represents very fairly the discharges. It depends, as before stated, almost altogether on the gauge relations, and, for this long transfer from St. Charles (778 miles), it is considered very satisfactory.

MEAN DISCHARGES FROM 1879 TO 1890.

In determining the mean discharges from 1879 to 1890, it was first found by trial that the *mean discharge* could not, with a satisfactory degree of approximation, be scaled on a discharge curve from the *mean gauge readings;* for it introduced sometimes a large and always a constant error. The discharge, scaled on a curve for the mean gauge reading, being smaller than the mean of the discharges scaled from the individual gauge readings on the same curve, on account of the higher gauge readings having discharges larger in more than a simple ratio. This source of error would cause the discharge corresponding to the mean gauge readings to be at times more than 30 per cent too small, and, as a general average for the whole period at the three points, about 6.6 per cent too small. It was, therefore, necessary to scale the discharges corresponding to individual gauge readings, and make up their daily means.

While the absolute position of the curves could be readily fixed in 1882 and 1883 from the gauge relations, combined with the discharge data taken on the river in those years, still the absolute positions of the curves for the other years was indeterminate; so that, after a preliminary study of the relations of the mean daily gauge readings had been made, it was concluded that the best method would be to scale all the discharges uniformly from the 1879 curves, as a first approximation, and revise these approximate values, in the comparison of the variation of discharge down the river.

For this the daily discharges scaled on the 1879 curves were plotted as daily variations, shifted by the time intervals to correspond with Kansas City dates; the three variations for each year at St. Charles, Kansas City, and Sioux City being plotted to the same zero of discharge scale, thus showing the changes in volume from point to point each day. From a study of these the most probable changes of plane were determined for periods that showed inconsistent values of discharge, and where observed discharges on the river gave positive data, and on these planes corrected values of discharge were scaled and substituted.

The most pronounced divergence from the 1879 curves shown seemed to be a permanent lowering of the curve at St. Charles after the high water of 1883, which, it was concluded, was connected with the marked change in channel there at that time, the river changing its course then from around the St. Charles Island to straight down the city front.

A special study of the relation of computed curve discharges at St. Charles, Grafton, and St. Louis, before and after 1883, was here made, in the hope of being able to definitely value this change at St. Charles. This, however, was not altogether successful, and these changes of plane were finally arbitrarily assigned values from the daily variations of discharge, as in the other periods.

\ sketch of Dike No. 7, showing the upper row of piling and the p waling and willow curtains. The mud and sand deposit and the p foot mat, all of which were determined by probings and soundings ta also indicated; stage of water, 672'.30.

photograph* of the dikes taken September 1, showing the deposit m preceding June rise. Stage of water, 668'.20.

\ photograph* of Dike No. 2, taken May 31, showing longitudinal br low curtains constructed during May. Stake of water, 672'.50.

FINANCIAL STATEMENT.

10 linear feet of waling:		
r	$422.13	
ings (nails, staples, and drift bolts)	217.63	
placing waling)	300.45	
		$94(
10 linear feet of willow curtains:		
ug willow brush	16.00	
(cutting brush)	51.80	
. hauling brush)	108.90	
ings (staples and wire)	43.84	
of construction	250.15	
		47(
appliances		!
penses (traveling expenses)		1'
ration		19(
al amount expended		1,62

ı, colonel, very respectfully, your obedient servant,

CHAS. F. POTTER,
Division Enginee

'ol. CHAS. R. SUTER,
orps of Engineers, U. S. A.,
President Missouri River Commission.

APPENDIX C 1.

.NUAL REPORT OF MR. CHAS. F. POTTER, DIVISION ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
Omaha, Nebr., July 1, 189

EL: I have the honor to submit the following report upon progress of w . charge at Omaha, Nebr., during the fiscal year ending June 30, 1891.

:e was maintained at Omaha throughout the year, from which all worl ha division was directed.

incipal works under my charge during the year consisted of the shore- nd the construction of willow curtains on the Sioux City dikes, eacl is been made the subject of a special report.

were no works of construction in operation during the year in the vici a.

·ter boat was made for the accommodation of the survey party in Septen ructing a cabin on barge No. 11, and hereafter it will be used as a bı boat on construction work.

vy sand deposit, made on the inclined portion of the ways during the J 890 was removed in the early part of October by using a jet of water fro ker pump.

ork of pulling out the boats onto the ways at the Council Bluffs boat y nmenced October 21 and finished November 20.

watchmen were employed during the winter in taking care of the plant auges at Sioux City, Blair, Omaha, and Plattsmouth were inspected and corrections made in the length of the cable when necessary.

pril 7 a project was submitted for the expenditure of the Council Bluffs a ade by the Missouri River Commission March 27.

*Omitted.

In the project an allowance was made for extensive repairs to plant, and a special detailed estimate of the same was submitted on the same day as the main project.

Both the project and estimates for repairs to plant were approved by you on April 9, but no actual work or expenditure connected with the new allotment was begun until May 1.

Work on repairs to plant commenced May 11,, and the decayed portions of the following boats were removed, viz, 8 barges 100 by 25 feet, 2 barges 64 by 16 feet, 2 quarter boats, 2 pile-sinkers, and 2 umbrella boats.

The lumber for repairs commenced to arrive on May 26, and since that date quarter boats Nos. 2 and 4 have been supplied with lower web strakes, floor strakes, and entire new bottoms.

The roofs of all covered boats, including quarter boats and pile-sinkers, were overhauled, and in most cases an entire new covering of canvas was used, and followed by two coats of paint and a covering of sand.

The tow-boat *Capitola Butt* was sent from Omaha to Nebraska City, Nebr., the latter part of May and returned with a tow consisting of 2 small quarter boats, 6 skiffs, and other engineer property that was left at the Nebraska City boat yard by the shore-line survey party in November.

There has been no break or destruction of any description during the year in any portion of the works of Missouri River improvement constructed during the past 3 years at Omaha and Sioux City.

FINANCIAL STATEMENT.

Expenditure from July 1 to May 1.

Construction of brush quarter boat:		
Material	$175.74	
Labor	168.62	
Subsistence	28.00	
		$372.36
Care of plant:		
Labor	1,174,27	
Subsistence	332.76	
		1,507.03
Pulling out boats:		
Labor	1,213.50	
Supplies	82.69	
Subsistence	383.49	
		1,679.68
General supplies		73.03
Sundry expenses (rent of office and telephone, traveling expenses, etc.)		693.15
Administration		3,027.08
Total		7,352.33

The above expenditures were divided between three allotments as follows:

Omaha allotment	$1,780.45	
Sioux City allotment	3,980.06	
Care of plant allotment	1,591.82	
		7,352.33

Council Bluffs allotment.

(Expenditure from May 1 to July 1.)

Repairs to plant:		
Material	3,061.50	
Labor	2,640.12	
Subsistence	705.96	
		6,407.
Care of plant:		
Labor	70.50	
Subsistence	22.85	
		93.
Towing:		
Labor	128.34	
Supplies	93.90	
Subsistence	34.36	
		256.

General supplies (tools, etc.)	$90.70
Sundry expenses (rent of office and telephone, traveling expenses, etc.)	108.20
Administration	1,041.34
Total	7,997.77

Total expenditure for the year ending June 30, 1891, $15,350.10.

I am, colonel, very respectfully, your obedient servant,

CHAS. F. POTTER,
Division Engineer.

Lieut. Col. CHAS. R. SUTER,
Corps of Engineers, U. S. A.
President Missouri River Commission.

APPENDIX D.

ANNUAL REPORT OF MR. S. WATERS FOX, DIVISION ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
St. Joseph, Mo., June 30, 1891.

COLONEL: I have the honor to submit the following report, and the accompanying maps and photographic views,* of the operations under my charge on the St. Joseph division of the Missouri River, during the fiscal year ending June 30, 1891.

IN THE VICINITY OF NEBRASKA CITY, NEBRASKA.

Work on this reach consisted in the extension of the Nebraska City Island revetment, and the care and repair of plant.

Revetment (see accompanying map a to á).—During the month of July, 1890, the shore bar at the head of the island eroded with a rapidity that indicated the early exposure to the current of the main bank. Preparations were begun for its protection, by the extension upstream of the revetment constructed the year previous.

A quarry was opened at Jones Point August 1, and operated until August 31, when the required quantity of riprap stone, 1546.71 cubic yards, had been procured. A brush party was put in the field August 3, and continued work until the 21st, procuring 460.3 cords of brush. As a portion of the bank to be protected had been graded the year previous it was thought that the balance of it could be done by hand; but the current was so swift and bank-caving so rapid that it became necessary to resort to the use of a jet. Pile-sinker No. 7 was put into service as a grader, and, between August 11 and 18, graded 853 linear feet of bank, in which were 2,245 cubic yards of earth. When weaving of mattress began, August 12, 940 linear feet of the main bank had been exposed, and there seemed to be no tendency to bank erosion higher up. The start with mattress was therefore made at point á on accompanying map, that distance above the head of the old revetment, and by August 27 the new work lapped the old, 100,031 square feet of mattress having been woven. The ballasting was finished September 2.

Cost exhibit in detail of 940 feet of revetment, Nebraska City, Nebr., 1890.

Classification and extent.	Cost per unit.	Cost each item.	Cost per linear foot.	Cost 940 feet revetment.
Procuring 511.2 cords of brush, viz:				
Stumpage, 323.75 cords	$0.0800	$33.90		
Cutting	0.3743	191.37		
Binding:				
Labor $106.00; Material 32.06	0.2700	138.06		
Hauling	0.2163	110.60		
Barging	0.1501	76.75		
Subsistence	0.3319	169.66		
Towage:				
Labor	0.2124	108.60		
Fuel	0.0833	42.60		
Subsistence	0.0804	41.10		
		912.64	$0.9709	$912.64

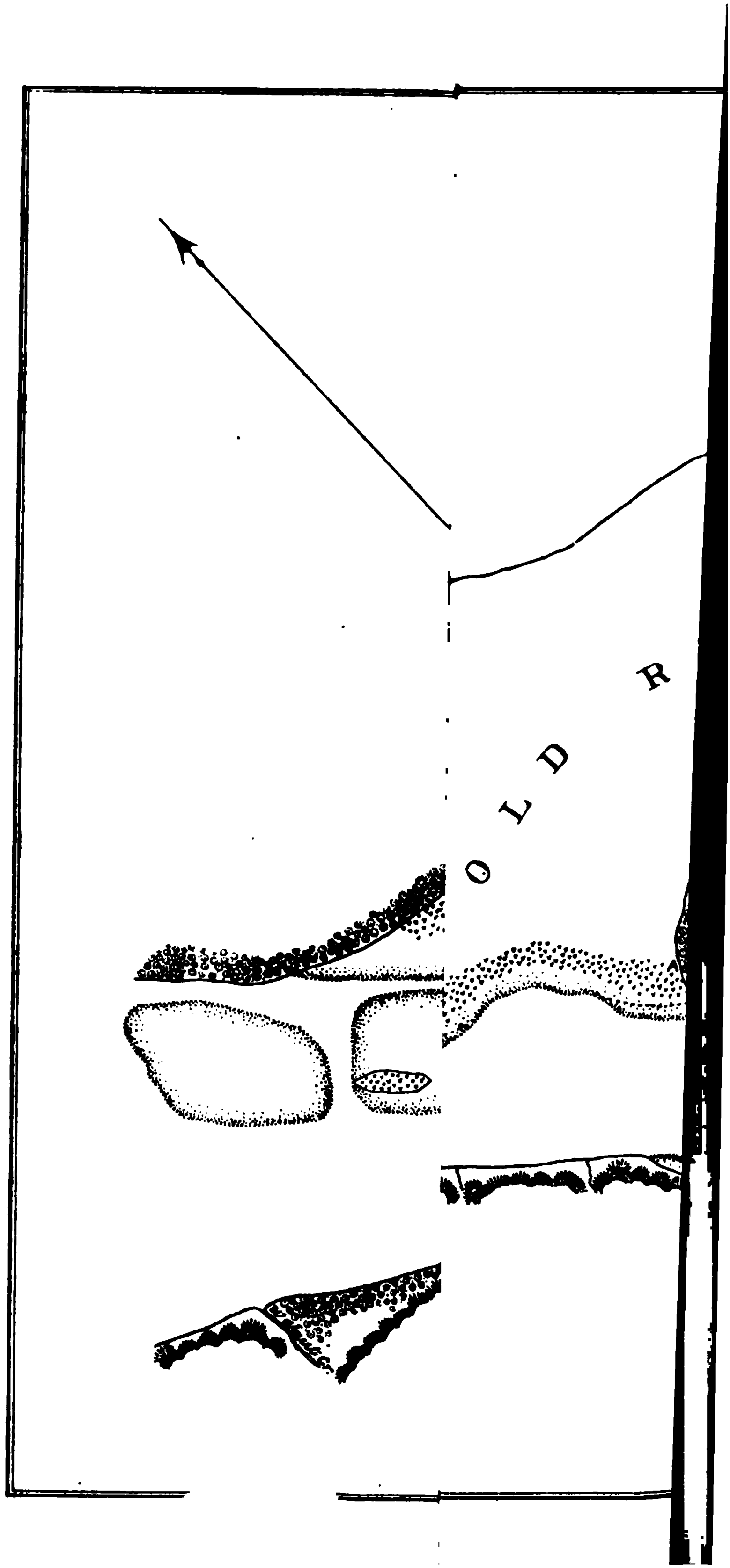
*Omitted.

Cost exhibit in detail of 940 feet of revetment, Nebraska City, Nebr., 1890—Continued.

Classification and extent.	Cost per unit.	Cost each item.	Cost per linear foot.	Cost 940 feet revetment.
Procuring 1,546.71 cubic yards rock, viz:				
Quarry privilege	$0.0100	$15.46		
Quarry supplies	0.0322	51.35		
Stripping	0.0869	134.12		
Quarrying	0.2484	383.92		
Barging	0.0824	127.50		
Subsistence	0.1824	282.20		
Towage:				
Labor	0.1534	238.07		
Fuel	0.0601	92.85		
Subsistence	0.0580	89.62		
		1,415.09	$1.5054	$1,415.09
Weaving 940 feet mattress, viz:				
Labor	.4295	403.70		
Subsistence	.2715	255.29		
	.7010	658.99	7.010	658.99
Anchorage 940 feet mattress, viz:				
Labor	.1072	100.85		
Subsistence	.0531	49.96		
Material:				
Strand ⅜ inches	.2969	279.11		
Cable 1¼ inches	.0922	86.69		
	.5494	516.61	.5494	516.61
Placing rock, 1,546.71 cubic yards, viz:				
Labor	.1214	187.70		
Subsistence	.0532	82.29		
	.1746	269.99	.2872	269.99
Hydraulic grading, 2,245 cubic yards, viz:				
Labor	.0353	79.20		
Fuel	.0061	13.75		
Subsistence	.0148	33.16		
	.0562	126.11	.1342	126.11
Total			4.1481	3,899.43

Bill of cost, 940 feet of revetment, Nebraska City, Nebr., 1890.

Classification and extent.	Cost.
323.75 cords of brush, stumpage at 8 cents	$33.90
187.45 cords of brush, stumpage free	
511.2 cords of brush, on barge	654.38
675 pounds binding wire, at 4¾ cents	32.06
5638.6 pounds wire strand ⅜ inches, at 4.95 cents	279.11
3650 feet 1¼-inch cable, at 2.37½ cents	86.69
Quarry privileges	15.46
Quarry supplies, powder, fuse, and coal	51.35
1546.71 cubic yards rock on barge, hired labor	927.74
Labor and subsistence, weaving	658.99
Labor and subsistence, anchorage	150.81
Labor and subsistence, hydraulic grading	126.11
Labor and subsistence, ballasting	269.99
Labor, fuel and subsistence, towage	612.84
Total cost 940 feet revetment	3,899.43


OLD R

Miscellaneous data and elements of cost exhibit, Nebraska City, 1890.

Classification and extent.	
Linear feet of mattress	940
Square feet of mattress	100,031
Total cost	$3,899.43
Cost per linear foot	$4.1481
Cost per square (100 square feet)	$3.8982
Number of meals issued to work	6,660
Subsistence cost	$1,003.28
Subsistence cost per capita per diem, labor	$0.1335
Subsistence cost per capita per diem, stores	$0.3184

Care and repair of plant.—As the fleet at Nebraska City had been increased by several pieces from the work at Rulo, it became necessary to provide additional storage ways in the yard on the island. This work was finished September 20, and the force discharged, except the watchman in care of the plant. One thousand eight hundred linear feet of ways were placed, at a cost of $274.

Assistant Jos. C. Meredith, who is in local charge at Nebraska City, having been detailed October 1, 1890, in charge of the party making a shore-line survey of St. Joseph Division of Missouri River, the pulling out of the fleet was deferred until the following month, when he was relieved for that purpose.

The first piece was gotten out November 14, the last November 19; in all, 17 pieces were pulled out of the river and placed on storage ways.

In December preliminary estimates of the cost of repairing the hulls were prepared and permission asked to remove the decayed parts before submitting final estimates. Under authority of your letter, dated January 21, 1891, this work was begun January 26, and finished March 11, at a total cost of $835.95.

A final estimate of all the needed repairs was submitted March 4, 1891. Authority covering the proposed repairs to wooden hulls was given in your letter dated April 8, 1891, and the work begun at once. Owing to delays in the receipt of lumber, progress was made slowly. By June 30, 1891, the following pieces had been repaired and launched, viz:

Small quarter boats belonging to Omaha Division	2
Barges, 16 by 65 feet	4
Barges, 25 by 100 feet	10
Pile sinker	1

Of the pieces left in the yard, 2 barges, 25 by 100 have been finished ready for launching; the balance, consisting of 4 barges, 25 by 100 feet, 2 quarter boats, 1 grader, 1 mattress boat, 1 steamer, *Sabrina*, have all had some work done on them.

Cost exhibit of repairs to hulls for the fiscal year ending June 30, 1891, at Nebraska City, Nebr.

Labor, class.	Work done, extent.		
Administration	Office and clerical work	$715.98⅓	
Care of plant	Watching boats and other property	221.00	$936.98⅓
Carpentering	Repairs, proper	2,310.95	
Calking	Repairs, proper	2,576.07⅓	
Blacksmithing	Repairs, proper	36.25	
Labor	Repairs, proper	514.77⅓	
Teaming	Repairs, proper	34.35	5,472.40
Launching boats			367.82⅓
Total, all classes			6,777.20⅔
Material:			
Plant material	Lumber, iron, oakum, etc	2,826.11	
Plant purchased	Tools	3.47	
Supplies	Oil, paint, and tallow	64.50	2,894.08
Total expenditures			9,671.28⅔

It is estimated that this work can be finished July 25, 1891, at a cost of $2,000.

IN THE VICINITY OF RULO, NEBRASKA.

Operations on this reach were confined to the completion of the revetment begun May, 1890. (See accompanying map, A to B.)

APPENDIX C.

ANNUAL REPORT OF MR. CHAS. F. POTTER, DIVISION ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
Omaha, Nebr., June 20, 1891.

COLONEL: I have the honor to submit the following report upon work of improving the Missouri River in the vicinity of Sioux City, Iowa, under my charge during the fiscal year ending June 30, 1891:

The highest stage of water in the river at this place since the dikes were constructed in 1889 was in July, 1890, the gauge then reading 674′.45, or about 6′.7 above standard low water.

The sand deposit in the vicinity of the middle and outer ends of the dikes, most of which was formed during the rise above mentioned, reached in many places within 1 foot of the crest of the rise.

The surface of the bar then formed was, however, very irregular; and there has since been a depression near the old Iowa bank, caused by a draw, starting in between Dikes Nos. 1 and 2 and running close to the high bank through the dikes below.

In anticipation of the coming June rise of 1891, which was thought from all reports would be of greater magnitude than any of the periodical rises of the past few years, it was thought best to strengthen the dikes with longitudinal braces and to place sufficient obstructions at the north ends of the dikes in the path of the draw to check the flow of the water and thereby cause the desired sand deposit.

A project for additional construction to the dikes, involving the above ideas, was submitted on May 18, and was approved two days later.

Work was commenced May 25, and the methods of construction then adopted and afterward carried out will be described under the heads of waling and curtains, as follows:

Waling.—The longitudinal braces, or waling, consisted of 6 inches by 8 inches by 20 feet pine timbers, drift-bolted to the upper side of the upstream line of piling in the dikes.

On the north 150 feet of the dikes two parallel lines of waling 42 inches apart between centers were placed; the upper edge of the top waling being 1 foot below the standard high-water line.

On the remaining portions of the dikes a single line of waling was used only, it being an extension of the top waling, running with a deflection corresponding with the slope of the top line of the piles, thus leaving the top of the waling at the outer end of the dikes 2 feet below standard high water.

Two drift bolts were used at each intersection of the waling with the piles, and were made of ¾-inch square iron, cut in lengths of 14 inches.

Curtains.—The curtains were constructed on the north ends of the dikes, extending across the draw and covering the same distance along the dikes as the double waling.

They consisted of selected willow brush of not less than 2½ inches in diameter at the butt end and 20 feet in length, placed in a vertical position, 6 inches apart, on the upper side of the dikes.

The butt ends were run down through the mud a distance of 7 feet, except where they came in contact with a hard bottom of sand or the foot mat through which the piles were driven 2 years ago.

The brush was fastened to each waling by staples made from $\frac{5}{16}$-inch round iron.

It was originally intended to place two longitudinal ⅝-inch cables parallel to and below the waling and to fasten them to the piling by heavy staples, and afterwards to wire the brush to the cables at each intersection, but before this could be accomplished a rise of the river to within 1 foot of the lower waling interfered.

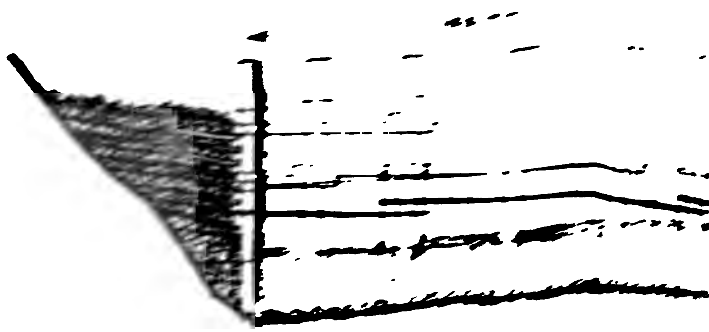
As a substitute for the proposed cables, three willows were lashed together, weighted with rock, and sunk in a horizontal position between the piling and the vertical willow brush to about midway between the lower waling and the mud, and then suspended by wires attached to the waling, thereby giving a lateral support to the vertical willows of the curtain.

All work at Sioux City was completed on June 13 and the force discharged.

ILLUSTRATIONS.

The map, sketch, and photographs accompanying this report are described as follows:

First. Map of the Missouri River in the vicinity of Sioux City, Iowa, surveyed in October, showing the location of the dikes; stage of water 667′.00.



Bill of cost, 4,922 feet of revetment at Rulo, Nebr., 1890.

Classification and extent.		Cost.
1,073.5 cords of brush, stumpage, at 8 cents		$85.78
100 cords of brush, stumpage, at 10 cents		10.00
1,124.3 cords of brush, stumpage, free		....
3,297.8 cords of brush on barge		2,711.59
3,600 pounds binding wire, at 4¾ cents		171.00
11,526 pounds wire strand, ⅜ inch, at 5 cents	$576.30	
12,267 pounds wire strand, ⅜ inch, at 4.95 cents	607.22	
		1,183.52
42,075 pounds cable, 1¼ inch, at 1⅛ cents		473.34
100 clips, at 20 cents		20.00
10,023.49 cubic yards rock, viz:		
Quarry privilege		50.00
Quarry supplies, powder, fuse, and coal		108.54
6,068.59 cubic yards rock procured by hired labor		2,996.82
3,862.99 cubic yards rock, purchased on barge, at $1.37½		5,311.61
9,191 cubic yards rock procured by forfeit		....
Labor and subsistence:		
Ballasting		1,626.04
Weaving		3,622.99
Anchorage		732.95
Labor, fuel, and subsistence:		
Hydraulic grading		595.54
Towage		1,422.16
		21,121.78

Miscellaneous data and elements of cost exhibit, Rulo, 1890.

Linear feet of mattress	4,922
Square feet of mattress	538,861
Total cost	$21,121.78
Cost per linear foot	$4.2937
Cost per square (100 square feet)	$3.9248
Meals issued to work (number)	17,810
Subsistence cost	$2,517.70
Subsistence cost per capita per diem, labor	$0.1292
Subsistence cost per capita per diem, stores	$0.2940

Since the completion of the revetment there has been but little change in the conditions of flow on the reach. The accompanying map shows the change in the shore line of the bend below the work.

Under date of September 26, 1890, I submitted a revised project with estimates of cost for the improvement of the reach.

IN THE VICINITY OF ST. JOSEPH, MISSOURI.

The operations on this reach consisted of repairs to plant, construction of pile dikes and revetment, and miscellaneous work incident thereto.

Repairs to plant.—The rebuilding of hydraulic graders Nos. 1 and 2 for use on the Omaha Division, which was begun last year was finished, with the exception of some of the steam fitting, July 23, 1890. The hull of grader No. 7 was also repaired. The force was then reduced to two watchmen in care of the property.

September 29, 1890, work was begun getting ready a fleet for use in pile dike construction. The United States steamer *Thetis* was thoroughly overhauled and launched. One barge, 16 by 65 feet, and pile sinker No. 13 were also repaired and launched. In the latter part of February, 1891, some minor repairs were made to the steamer *Thetis* and pile sinker No. 13 before putting them in service.

April 23, 1891, the repairs of the hulls on the ways in the St. Joseph boat yard was begun; by June 18 it was finished, and all of the pieces, consisting of two hydraulic graders and three barges, 25 by 100 feet, were in the water. The total cost of the repairs to plant during the year was $3,439.50.

In a letter dated July 31, 1890, I called your attention to the conditions of flow that obtained at the time in the reach above the head of Bon Ton Bend, reviewed the history of the changes of regimen in the reach from 1884, of my recommendations from time to time concerning its improvement; and, finally, submitted a project with estimates of cost for its improvement at that time.

As was expected, the flow from the Kansas Chute, coming as it did in a direction almost normal to the trend of the shore line at the head of Bon Ton Bend, soon

proved too much for the revetment, and a slip in the mat occurred September 10, and was made the subject of a special report.

A project for the improvement of those conditions, prepared in accordance with your instructions, was submitted under date of September 29. It contemplated the development of a new channel, as shown on the accompanying map by the dotted lines, from point B on the right bank through the island bar to the left bank above the head of Bon Ton revetment, and the construction of new revetment in Bon Ton Bend where it was exposed to the flow from the Kansas Chute.

The proposed rectification was to be accomplished by means of permeable pile dikes, constructed under specifications similar to those under which the Atchison dikes were made, and located as shown on the map, B to C. For immediate relief and for the protection of Gladden Point pending the rectification, the dikes D to E were to be constructed. A revetment from A to B was also provided for in the estimates. This was to be constructed only in case it became necessary for the protection of the upper system of dikes. This project was approved, and, in accordance with your verbal instructions of October 7, 1890, preparations were at once begun for the construction of the proposed dikes D, E, in the lower system, and repairs to the Bon Ton revetment.

One small barge (16 by 65 feet) and a mattress boat were rafted down from Nebraska City. The balance of the fleet, consisting of the steamer *Thetis*, pile sinker No. 13, and three small barges, were supplied from the yards at this point. One of the small barges was provided with ways for use in constructing foot mattress for the dikes. As the only quarter boats on the division were on the ways at Nebraska City and unserviceable, temporary quarters were erected on the bank convenient to the work and equipped.

Pile dikes D to E (lower system).—The piles, wales, braces, bolts, and strand for the dikes were purchased in open market. The brush and rock used were procured by hired labor. Brush cutting was begun October 16, 1890. A quarry was opened October 15, 1890.

Pile sinking was begun October 21, and was continued with but little interruption until December 3, when, on account of running ice, work had to be suspended. Up to that date 275 piles had been sunk, with an average penetration of 16.5 feet per pile; of these piles, 248 were in the dike and 27 for anchorage. The placing of wales and braces and making shore connections were finished December 13, 1890.

When the ice began running some of the foot mattress had not been sunk, and rock could not be gotten to it. An effort was made to sink it with bags of sand, but was only partially successful, as the ice formed about the piles very rapidly, and soon blocked to the bottom. December 19 the ice moved out and the steamer *Thetis* was put in service, with two small barges, towing rock for use in sinking the foot mat. By December 24 it was all down in good shape, and the steamer laid up again. The total length of dike completed was 1,353 feet.

Work was resumed on Dike No. 3 of the lower system March 27, 1891. All of the piles (23 in dike and 3 for anchorage) necessary for the extension of the dike to its projected length had been sunk and the fleet removed to the upper system, when a sudden rise of the river produced a scour of about 9 feet along the new work before the foot mattress was sunk; the anchorage gave way first, throwing the weight of the foot mat against the piles in the dike; their penetration having been reduced by scour to about 6 feet, the weight proved too great for that portion of the dike, and resulted in overturning all but four bents next the old work.

Cost exhibit in detail of 1,485 linear feet of pile dike, St. Joseph, Mo., 1890 and 1891, lower system.

Classification and extent.	Cost per unit.	Cost each item.	Cost per linear foot.	Cost of 1,485 linear feet of dike.
1,604 linear feet of foot mat, viz:				
Labor, weaving	$0.2955	$474.02		
Subsistence	.0707	113.50		
Material:				
441 cords of brush	1.2095	533.39		
25 cords of brush				
Barging 466 cords of brush	.0495	23.07		
1,600 pounds ⅜-inch strand—free				
526 pounds strand	.0049	27.54		
Moving 1,600 pounds ⅜-inch strand	.0575	9.20		
		1,180.72	$0.7951	$1,180.7[illegible]

Cost exhibit in detail of 1,485 linear feet of pile dike, etc.—Continued.

Classification and extent.		Cost per unit.	Cost each item.	Cost per linear foot.	Cost of 1,485 linear feet of dike.
Pile work in dikes:					
Material, cottonwood piles, viz:					
106 piles, at $1.35	$143.10				
165 piles, at $1.22½	202.12				
Labor, preparing piles	77.15				
Subsistence, preparing piles	10.50				
Cost of piles ready for sinking		$1.5973	$432.87		
Labor, sinking 271 piles		1.4783	400.62		
Subsistence, sinking 271 piles		.2400	65.00		
Fuel, sinking 271 piles		.3271	88.65		
Supplies, sinking 271 piles		.0400	10.78		
Cost of 271 piles in place		3.6827	997.92	$0.6720	$997.92
Anchorage,					
Material:					
4 piles, at $1.35	$5.40				
26 piles, at $1.22½	31.85				
414 pounds ⅜-inch strand at 4.9 cents	20.29				
Material, cost for 1,485 linear feet		.0388	57.54		
Labor, sinking anchorage, 1,485 linear feet		.0535	79.49		
Fuel, sinking anchorage, 1,485 linear feet		.0065	9.70		
Subsistence, sinking anchorage, 1,485 linear feet		.0044	6.50		
Total anchorage cost		....	153.23	.1032	153.23
Waling and bracing:					
Labor, placing wales and braces		.2023	300.42		
Subsistence		.0408	60.50		
Material, 2,524 feet, B. M., oak lumber:					
Transportation		.0101	25.76		
30,426 feet, B. M., yellow pine lumber per M		15.9000	460.22		
480 bolts		....	....		
820 bolts per pound		.0673	91.12		
Washers and nails		.0124	18.49		
Labor, handling materials		.0300	44.10		
Subsistence, handling materials		.0066	9.50		
			1,010.11	.6802	1,010.11
Ballasting foot mat, viz:					
Labor		.1272	204.15		
Subsistence		.0069	11.00		
Material, 131 cubic yards old rock:					
Barging 131 cubic yards old rock		.2893	37.90		
Towage rock:					
Labor	$126.16				
Fuel	26.27				
Supplies	3.00				
Subsistence	20.66	1.3436	176.09		
Material, 226 cubic yards rock on bank		.6405	144.75		
Towage rock:					
Labor	$237.79				
Fuel	49.60				
Supplies	4.50				
Subsistence	32.20	1.4340	324.09		
Material, sacks and twine		.685	34.54		
			932.52	.6280	932.52
Curtain (574 linear feet):					
Labor, weaving		.1591	91.35		
Subsistence, weaving		.0091	24.00		
Material, 492 poles:					
Stumpage	$1.50				
Cutting	16.43				
Handling	14.57	.0066	32.50		
Material, 34 cords brush		1.2095	41.12		
			188.97	.1273	188.97
Total		....	....	3.0058	4,463.47

Bill of cost, 1,485 feet of pile dike, St. Joseph, Mo., 1890 and 1891, lower system.

Classification and extent.	Cost.
500 cords of brush on barge	$597.58
2,576 pounds of $\frac{3}{8}$-inch strand	57.03
301 cottonwood piles	382.47
2,524 feet oak lumber (transportation only)	25.76
30,426 feet yellow-pine lumber	460.22
1,300 bolts	91.12
504 sacks and 3 pounds twine	34.54
492 poles	32.50
357 cubic yards rock on barge	182.65
Supplies (nails and washers)	18.49
Labor and subsistence, weaving foot mat	587.52
Labor, subsistence, fuel, and supplies, pile dike	652.70
Labor, subsistence, and fuel, anchorage	95.69
Labor and subsistence:	
Waling and bracing	414.52
Ballasting	215.15
Making curtains	115.35
Labor, subsistence, fuel, and supplies, towage	500.18
Total	4,463.47

Miscellaneous data and elements of cost exhibit, 1,485 feet pile dike.

Classification and extent:		
Linear feet of foot mat	1,604	
Linear feet of pile dike	1,485	
Total cost	$4,463.47	
Cost per linear feet		3.0058
Subsistence, cost per capita per diem:		
Labor		0.1096
Stores		0.3885

Cost exhibit in detail of brush and rock procured; season, fall 1890.

Classification and extent.	Cost per unit.	Cost each item.	Cost per cord and cubic yard.	Total cost each class.
Procuring 1,123 cords brush:				
Stumpage:				
299 cords				
824 cords	$0.1000	$82.40		
Survey to decide ownership of brush: Labor .... $23.20, Sundries .... 4.30 } for 824 cords	0.0333	27.50		
Cutting	0.3134	351.92		
Binding	0.1730	194.25		
Loading wagons	0.0331	37.20		
Hauling	0.4389	492.96		
Unloading wagons	0.0522	58.60		
Subsistence	0.1010	113.50		
Cost at bank			$1.2095	$1,358.33
Procuring 328 cords brush:				
Stumpage	0.1500	57.30		
Making road	0.0123	4.70		
Cutting	0.3986	152.28		
Binding: Labor .... $61.90, Material 2.38	0.1683	64.28		
Loading wagons	0.0656	25.06		
Hauling	0.5619	214.65		
Unloading wagons	0.0662	25.30		
Cost at bank			1.4220	543.56
Procuring 4,012 cubic yards rock:				
Stripping	0.1160	465.25		
Quarrying	0.2416	969.15		
Loading wagons	0.0504	202.20		
Hauling	0.1810	726.10		
Supplies	0.0307	123.24		
Subsistence	0.0206	82.50		
Cost at bank			0.6405	2,569.44

Cost exhibit in detail, procuring 782 cords of brush, 1891, St. Joseph, Mo.

Classification and extent.	Cost per unit.	Cost each item.	Cost per cord.	Cost of 782 cords brush.
Stumpage	$0.1000	$78.20		
Cutting	0.2617	204.67		
Binding:				
Labor ... $106.20; Material ... 24.25	0.1668	130.45		
Loading wagons	0.0276	21.63		
Hauling	0.3608	282.17		
Unloading wagons	0.0391	30.60		
Subsistence	0.1862	145.58		
		893.30	$1.1422	$893.30

Pile dikes B, C, upper system.—The materials for these dikes were accumulated during the winter.

The piles, wales and braces, bolts, and three-eighth-inch wire strand, were purchased in open market. The piles were cottonwood, of minimum diameters at top and butt, of 9 and 14 inches respectively. The wales and braces were of long leaf yellow pine, and all 4 by 8-inch stuff, except the direct horizontal braces, which were 4 by 6 inches. Machine bolts were used with cast washers at both ends, and were three-fourths inch and seven-eighths inch in diameter; the former being used only in the 4 by 6 inch stuff. The arrangement of piles, wales, and braces was the same as that used on the Atchison dikes. The foot mattress was woven of a uniform width of 40 feet, and so placed that 28½ feet of its width was on the upstream side of the center line of the dikes.

In the latter part of March the boarding shanty was moved to Greyback Island, at the head of the dikes, and pile sinking begun April 3. Work was suspended May 26, to allow time for the development of a new channel. At that time 1,458 linear feet of dike had been completed; but dike 4 started at a shore bar 352 feet from the main bank, with only the foot mattress made. On June 8, when this bar was covered with water to a sufficient depth to float the sinker, work was resumed, and by June 18 the dike was connected with the main bank, making a total length of dike in the upper system of 1,810 feet. The accompanying map shows the progress of the work. Dikes 3 and 4 will be extended to their projected lengths as soon as expedient.

Cost exhibit in detail of 1,810 linear feet of pile dike, St. Joseph, Mo, 1891, upper system.

Classification and extent.		Cost per unit.	Cost each item.	Cost per linear foot.	Cost of 1,810 linear feet of dike.
Foot mattress, 1,956 linear feet:					
Labor, weaving		$0.2644	$517.16		
Subsistence, weaving		.1554	304.01		
Material:					
51 cords brush		1.4229	72.57		
641 cords brush		1.1422	732.15		
Labor, barging		.1383	95.70		
Towage:					
Labor	$81.80				
Fuel	25.92				
Subsistence	34.72				
Supplies	2.00				
		.2087	144.44		
Material, 2,572 pounds, 3/8-inch strand		.0415	106.74		
			1,972.77	$1.0900	$1,972.77
Pile work in dikes:					
417 piles on bank, at $3.30½	$1,378.18				
Rafting and inspection	152.19				
Towage:					
Labor	308.70				
Fuel	96.00				
Subsistence	50.92				
Supplies	5.00				
Cost of 417 piles delivered at work	1,990.99				
Cost per pile	4.7744				

Cost exhibit in detail of 1,810 linear feet of pile dike, etc.—Continued.

Classification and extent.	Cost per unit.	Cost each item.	Cost per linear foot.	Cost of 1,810 linear feet of dike.
Material:				
328 cottonwood piles, at $4 7744 …… $1,566.00				
Labor preparing same …… 120.02				
Cost of 328 piles prepared for sinker	$5.1403	$1,686.02		
Labor, sinking	1.5774	517.40		
Subsistence, sinking	.7670	251.54		
Fuel, sinking	.2964	97.22		
Supplies, sinking	.0576	18.90		
		2,571.08	$1.4205	$2,571.08
Anchorage:				
Material, 60 cottonwood piles	4.7744	286.46		
Labor, sinking	.0987	178.67		
Fuel, sinking	.0174	31.48		
Subsistence, sinking	.0378	65.84		
Material, 3,144 pounds ⅝ inch strand	.0415	130.48		
		692.93	.3828	692.93
Walling and bracing:				
Labor, placing	.1634	295.80		
Subsistence placing	.0776	140.50		
Material:				
832 feet oak lumber				
41,710 feet yellow pine lumber	.0185	771.64		
1,610 bolts	.0918	147.80		
207 pounds washers	.0350	7.24		
Labor, handling material	.0637	118.90		
Towage:				
Labor …… $66.56				
Fuel …… 21.12				
Subsistence …… 4.12				
Supplies …… 2.00	.0518	93.80		
		1,575.68		1,575.68
Ballasting:				
Labor, placing	.2222	93.78		
Subsistence, placing	.2100	88.60		
Material:				
422 cubic yards rock	.6405	270.29		
145 sacks	.0825	11.96		
Labor, barging rock	.1934	81.60		
Towage:				
Labor …… $189.93				
Fuel …… 57.60				
Subsistence …… 68.67				
Supplies …… 2.00	.7548	318.20		
		864.43	.4775	864.43
Curtain (1,712 linear feet).				
Labor, cutting 4,827 poles …… 21.95				
Subsistence, cutting 4,827 poles …… 10.67				
Hauling, cutting 4,827 poles …… 45.28				
Cost of cutting 4,827 poles …… 77.92				
Cost per pole …… .0161				
Labor, making	.1098	187.94		
Subsistence, making	.0447	76.54		
Material, 3,752 poles	.0161	60.56		
		325.04	.1796	325.04
Grand total			4.4209	8,001.93

Bill of cost of 1,810 linear feet of pile dike, St. Joseph, Mo., 1891.

Classification and extent.	Cost.
692 cords of brush on barge	$900.42
5,816 pounds ⅜-inch galvanized wire strand	237.22
388 cottonwood piles prepared for sinker	1,972.48
422 cubic yards rock on barge	351.89
145 sacks	11.96
832 feet oak lumber	....
41,710 feet yellow pine lumber	771.64
1,610 bolts	147.80
207 pounds washers	7.24
3,752 poles	60.56
Labor and subsistence, weaving foot mat	821.17
Labor, subsistence, fuel, and supplies, sinking dike	885.06
Labor, subsistence, and fuel, sinking anchorage	275.99
Labor and subsistence:	
Placing wales and braces	555.20
Ballasting	182.38
Making curtains	264.48
Labor, subsistence, fuel and supplies, towage	556.44
Total	8,001.93

Miscellaneous data and elements of cost exhibit, 1,810 feet of dike.

Classification and extent:	
Linear feet of foot mat	1,956
Linear feet of pile dike	1,810
Total cost	$8,001.93
Cost per linear foot	$4.4209
Subsistence cost per capita per diem:	
Labor	$0.0798
Stores	$0.3060

Revetment repairs.—Bank grading for this work began at the St. Joseph Water Company's suction pipe October 30 and was finished November 13. One thousand five hundred and fifteen linear feet of bank were graded. In this were contained 3,510 cubic yards of earth, brush, and rock. The weaving of mattress was begun at the same point November 13. One thousand two hundred and forty linear feet, or 140,214 square feet, had been woven by December 3 (see map, X to Y), when work was suspended on account of running ice.

Three hundred and two cubic yards of rock were used in sinking the mattress at that time, the balance being left until early spring. In March, 1891, the full quantity of ballast was distributed on the work.

Cost exhibit in detail of 1,240 linear feet of revetment, fall of 1890.

Classification and extent.	Cost per unit.	Cost each item.	Cost per linear foot revetment.	Cost of 1,240 feet revetment.
Hydraulic grading, 3,510 cubic yards, viz:				
Labor	$0.0476	$167.02	$0.1348	
Supplies	.0042	14.62	.0117	
Subsistence	.0060	21.00	.0169	
Fuel	.0174	61.30	.0494	
	.0752	263.94	.2128	$263.94
Weaving 1,240 linear feet of mattress:				
Labor	.7370	913.73	....	
Subsistence	.1347	167.00	.8717	
Material:				
322 cords brush at work	1.4229	458.17	....	
648 cords brush on bank	1.2095	783.76	....	
Moving 648 cords brush to work, viz:				
Loading and unloading barges	.2935	190.20	....	
Subsistence	.1420	92.00	....	
Towage:				
Labor	.4100	224.62	....	
Supplies	.0077	5.00	....	
Fuel	.0630	40.41	....	
Subsistence	.0558	36.14	.14762	
		2,911.43	.23479	2,911.43

Cost exhibit in detail of 1,240 linear feet of revetment, fall of 1890—Continued.

Classification and extent.	Cost per unit.	Cost each item.	Cost per linear foot revetment.	Cost of 1,240 feet revetment.
Anchoring 1,240 feet revetment, viz:				
Labor	$0.1682	$208.52		
Subsistence	.0375	46.50	$0.2057	
Material:				
Strand, ⅜-inch, 8,900 pounds	.0490	436.10	.3517	
Cable, 1¼ inch, 4,622 feet	.0240	110.93	.0894	
Clips, No. 59	.2571	15.17	.0122	
		817.22	.6590	$817.22
Ballasting 1,240 linear feet revetment:				
Labor, placing 2,346 cubic yards rock	.1864	437.31		
Subsistence	.0336	79.00	.4164	
Material, 2,346 cubic yards rock	.6405	15,502.61	1.2117	
	.8712	2,018.92	1.6281	2,018.92
Grand total			4.8478	6,011.51

Bill of cost, 1,240 linear feet of revetment, St. Joseph, Mo., 1890.

Classification and extent.	Cost.
970 cords of brush on barge at work	$1,524.13
8,900 pounds ⅜-inch strand	436.10
4,022 feet 1¼-inch cable (second-hand)	110.93
59 clips	15.17
2,346 cubic yards of rock	1,502.61
Labor, subsistence, fuel and supplies, hydraulic grading	263.94
Labor and subsistence:	
Weaving mattress	1,080.73
Anchorage	255.02
Ballasting	516.31
Labor, fuel, subsistence and supplies, towage	306.57
Total	6,011.51

Miscellaneous data and elements of cost exhibit, 1,240 feet revetment.

Classification and extent:	
Linear feet of mattress	1,240
Square feet of mattress	140,214
Total cost	$6,011.51
Cost per linear foot	$4.8478
Cost per square (100 square feet)	$4.2873
Subsistence cost per capita per diem:	
Labor	$0.1098
Stores	$0.3885

Belmont Bend revetment.—An item for the protection of Belmont Bend has always had place in the project for the improvement of the St. Joseph Reach. At a meeting held in St. Louis March 26, 1891, the Commission allotted the sum of $101,000 for the continuation and completion of the revetment in Belmont Bend, and, in accordance with your verbal instructions of that date, I prepared and submitted, under date of April 6, a project for the expenditure of the allotment. This project, which was approved, contemplates the construction, during the current season, of 13,000 linear feet of standard revetment in Belmont Bend, beginning at a point shown on the accompanying map at F.

As the only plant on the division not in use was at Nebraska City, in an unserviceable condition, the work in Belmont Bend was late getting started.

A quarry was opened in the bluffs at the head of the bend May 19, 1891. A small force began cutting brush May 26. Bank grading was begun May 30, with hydraulic grader No. 2.

Quarters for the mattress party were erected on one of the 100 by 25 feet barges, and as soon as it was finished, June 9, a force was organized, and weaving mattress began the day following. Owing to the delay in getting the mattress party started,

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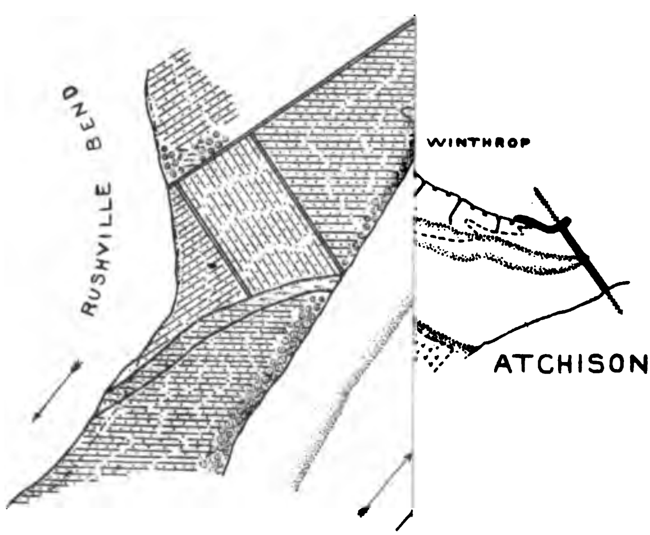
W.



S. Waters Fox, Dir. Eng'r

the bank grading got so far ahead that it became necessary to suspend grading June 9. Subsequently this work was resumed for a few days, and some regrading done. It was finally suspended June 20. The total length of bank graded was 1,285 feet; the number of cubic yards of earth removed was 16,919.

June 20 the stage of water was so high (9.68 feet above standard low water) that weaving was suspended also. Up to that time 746 linear feet, or 89,834 square feet, of mattress had been woven.

The head of the old revetment in Elmwood Bend is exposed and liable to considerable loss from a flanking movement of the shore line, due to erosion; the actual length of revetment that it will be necessary to construct in order to lap it is, therefore, indefinite; and the funds allotted for the work are no more than will probably be needed to cover the distance as it was at the time the project was submitted. The bank is caving very rapidly in the lower portion of Belmont Bend and it is proposed to begin work there with two mattress parties as soon as the June rise shall have passed.

In this way it is hoped, too, that the loss to the old work may be limited.

IN THE VICINITY OF ATCHISON, KANSAS.

The only work done on this reach during the year was the construction of new curtains on the dikes, some minor repairs to the bracing, and the rehandling of piles and lumber stored there.

Work was begun April 6, 1890, in accordance with my project dated March 31, and approved by you under date of April 3. It was finished April 11.

Three thousand five hundred linear feet of willow curtains were woven in place on the dikes. The meshes were diamond shaped, and averaged about 100 square inches in area. The brush were lashed together with wire at all intersections and to the wales. The broken and missing wales and braces, of which there were a few, were replaced. The lumber and piles stored on the bank were rehandled with a view to drying them and giving proper ventilation. This latter work was not finished until April 17. The entire force was then discharged, except the watchman.

Detail of cost of placing 3,500 feet of new curtain on Atchison dike, April, 1891.

Labor, weaving and placing curtain, and replacing wales and braces	$345.40
Construction material, brush and wire	55.30
Plant purchased	2.50
Traveling expenses—	
April	40.30
March	9.20
Total cost of new curtains	452.70

Cost of rehandling lumber and piles.

Labor	$76.05

Under date of October 6, 1890, I submitted a revised project with estimates of cost for the improvement of the reach.

The accompanying map shows the changes of shore line during the year.

The accretions behind the dikes have increased considerably during the year. A middle bar has formed in the reach in front of the dikes and the major portion of the discharge is passing down to the right of it. Under this action the shore bar on the right bank has receded as shown on the map.

The accompanying photographic views * showing the reach at the dikes were taken October 1, 1890.

SURVEYS.

A survey was made, August 6 to August 14, of the St. Joseph Reach, from a point about 8 miles above the head of Bon Ton Bend to the St. Joseph Bridge.

August 17 to 30, a survey was made of the Atchison Reach from Geary City, Kans., to the Atchison Bridge. Tracings of the maps prepared from these surveys accompanied the revised projects for the improvement of these reaches under dates of September 29 and October 6, respectively.

In the fall of the year, the survey of the St. Joseph division, omitting the two reaches just mentioned, was assigned to me. It was made the subject of a special report to the secretary of the Commission.

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* Omitted.

Partial shore-line surveys were made June 2 to June 9, 1891, in the vicinity of Nebraska City, Rulo, and Atchison.

Partial shore lines and hydrographic surveys were made from time to time in the vicinity of the dikes on the St. Joseph Reach, for information as to their effects on the stream.

I am, colonel, with great respect, your obedient servant,

S. WATERS FOX,
Division Engineer.

Lieut. Col. CHAS. R. SUTER,
Corps of Engineers, U. S. A.,
President Missouri River Commission.

APPENDIX E.

ANNUAL REPORT OF MR. SAMUEL H. YONGE, DIVISION ENGINEER, 1891.

MISSOURI RIVER COMMISSION,
OFFICE OF DIVISION ENGINEER,
Kansas City, Mo., June 30, 1891.

COLONEL: I have the honor to submit my report of operations pertaining to the improvement of the Missouri River for the fiscal year ending June 30, 1891.

As the funds alloted from the appropriation of August 11, 1888, for constructing works of improvement had been practically exhausted at the close of the fiscal year ending June 30, 1890, and no authority was received to proceed under the allotment for "repair and maintenance of works in the vicinity of Kansas City" and that of the "systematic improvement of the first reach," under the appropriation of September 19, 1890, till April 30 and May 19, respectively, no construction work of any extent could be carried on before the close of the fiscal year, and the operations were confined chiefly to care of plant and making special surveys and a shore-line survey from the vicinity of Weston, Mo., to the mouth of the Missouri River, for which last work a separate report has been submitted to the secretary of the Commission.

IMPROVEMENT WORKS IN THE VICINITY OF KANSAS CITY, MISSOURI.

The project for improvement works in the vicinity of Kansas City, Mo., approved by the Missouri River Commission March 27 and May 12, comprises such accessory works and extensions to works formerly constructed as were required for the maintenance and preservation of the latter, as follows, viz:

The protection of the stream ends of the four dikes constructed in Little Platte Bend in the summer of 1889, by means of woven mattress aprons, to prevent the outer ends of the dikes from being scoured out; the completion of the bank protection in Little Platte Bend, by constructing a revetment extending from the head of the revetment of 1889 to a point about 1,600 feet distant, upstream, above which point the bank is protected by the dikes; the repairs of the upper bank projection work of the Kaw Bend revetment, from which the stone ballast had been removed by ice and other causes; the protection, by revetment, of the left bank of the river opposite Kansas City, above the Harlem dikes, to guard the dikes against flanking; and the completion of the Kansas City system of dikes by extending dikes I and II and constructing dikes III, IV, and IX (vide accompanying map), which work was considered essential in contracting the river to an average width of 850 feet and thereby producing a more stable regimen.

HARLEM REVETMENT.

As the time was too short to make the necessary preparations and complete any one of the works contemplated in the project before a high stage of water was to be expected, it was decided to attempt, before the June rise, besides the construction of the Harlem revetment, only that of such portions of the Kansas City dikes as lie next to shore, where the work would not be too greatly interfered with by driftwood.

On account of unavoidable delays in getting the floating plant calked and launched and, consequently, in the delivery of piling and willows at the site of the work, construction could not be begun till May 26.

About this time the river, which before had been at a moderately low stage, in consequence of heavy rains rose 4 feet, to a mid-stage, which is too high for constructing mattress work properly.

The work was, however, proceeded with till June 2, when, on account of a further rise of about 4 feet, and the accumulation of large quantities of driftwood under and over the mattress, it became necessary to sink the mat and suspend work.

The revetment is to extend from A to C, a distance of 2,740 feet; the mattress constructed extends from A to B, 700 feet. (Vide map.)

The mattress is of the standard type used on Kansas City division as described in former reports. It extends to a stage of about $6\frac{1}{4}$ feet above standard low water, and has a width of about 75 feet.

The following statement shows the quantities of materials used and the cost of the work, but the figures given do not furnish a proper criterion for comparison with other similar work, as the work is incomplete and too limited in extent.

Statement.

Class of work, etc.	Price of materials.	Cost of each class of work.	Total.
Sinking 164 revetment anchorage piles:			
Labor and subsistence		$195.24	
5,329 linear feet piling	$0.08023	427.55	
120 bushels coal	0.11575	13.89	
20 pounds 8-inch spikes	0.0325	.65	
			$637.33
Weaving 48,540 square feet of mattress:			
Labor and subsistence		429.42	
285 cords of brush	1.86236	530.77	
3,646 pounds $\frac{3}{8}$-inch wire cable	0.045	164.07	
1,150 pounds $\frac{1}{4}$-inch wire cable	0.040	46.00	
95 $\frac{3}{8}$-inch iron cable fastenings	0.08	7.60	
40 $\frac{1}{4}$-inch iron cable fastenings	0.10	4.00	
			1,181.86
Sinking 34,600 square feet of mattress:			
Labor and subsistence		49.58	
158.6 cubic yards of stone	0.98774	156.66	
			206.24
Miscellaneous:			
Administration and incidental expenses		334.48	
Steamboat service		251.39	
Preparing for work		114.47	
Care of plant in service		202.11	
			902.45
Total			2,927.88

KANSAS CITY SYSTEM OF DIKES.

When the construction of the Harlem revetment had to be suspended on June 2, that of Dikes III and IV of the Kansas City system was taken up.

As parts of these dikes were to be placed across a high bar adjoining the right bank, advantage was taken of the fact that this bar was covered by water to a depth of several feet by sinking the piles by means of the jet, instead of using a hammer driver as had been originally intended.

The work proceeded slowly on account of the almost incessant rains in the early part of June, and considerable time was lost in keeping the pile-sinker, barges, and foot mat clear of driftwood.

According to the plan submitted, Dike III is to be about 1,470 feet long, as follows, viz: The first 630 feet next to the shore to consist of a single row of piles, with a foot mat 11 feet wide; the next 620 feet, of a double row, with a foot mat 21 to 24 feet wide; and the remaining 220 feet, of a triple row, with a foot mat from 35 to 65 feet wide; the foot mat to be strengthened by wire cables $\frac{3}{8}$-inch in diameter wherever its width exceeds 25 feet.

The single-row part of the dike is to be braced by one string of wales drift-bolted to the piling near the top, and the double and triple row parts are to be braced in the same manner as was done in the case of the dikes constructed in this vicinity in 1889, which was fully described in my report for that year.

On account of the high water and swift current only the following work could be done, viz: the piles for the single and 608 feet of the double-row parts were sunk, the foot mat for the single-row and 347 feet of the double-row parts constructed and sunk, and 350 feet of the single-row part braced in the manner indicated above.

The piles are all sunk point down, with about 10 feet between centers, in the direction of the dike, for the single-row part, and 8 feet for the double-row part, and 10 feet between rows where more than one row of piles are used.

The average penetration of the piles on the single-row part is 17.1 feet and on the double-row part 18 feet.

The foot mat was woven from deck punts 8 feet wide by 18 feet long, with the forward end inclined, from which the mat was launched. Under favorable circumstances the construction of foot mat proceeded very rapidly, about 200 linear feet of the 11-foot mat and 160 linear feet of the 21-foot mat constituting a day's work for a gang of 10 to 12 men.

According to the project Dike IV is to be 725 feet long, to consist of 600 feet of double and 200 feet of triple-row dike of the same construction as the corresponding parts of Dike III.

Only the pile sinking for 248 feet of the double-row part of Dike IV was done.

Dike work was stopped June 15 by the high stage of water, which prevented the bracing and foot mat from being placed on the parts of the dikes exposed to the swiftest current.

On June 16 large quantities of driftwood lodged against the piles, causing 49 in Dike III, which were situated beyond the point to which the foot mat had been carried, to break off and scour out. Sixteen piles in Dike IV were carried out in the same manner.

The following statements show the quantities of materials used and cost of constructing the dike work described:

Statement for 630 linear feet of single-row dike.

Class of work, etc.	Prices of materials.	Cost of each class of work.	Total.
Sinking 60 piles:			
Labor and subsistence		$102.83	
83 bushels coal	$0.11575	9.61	
17 pounds 8-inch spikes	.0325	.55	
1,950 linear feet piling	.08023	156.45	
			$269.44
Bracing 350 linear feet of dike.			
Labor and subsistence		39.15	
70 pounds $\frac{5}{8}$-inch square iron	.022	1.54	
18 wales, 486 linear feet	.0317	15.41	
			56.10
Weaving and sinking 635 linear feet of foot mat, 11 feet wide:			
Labor and subsistence		103.18	
47.5 cords brush	1.86236	88.46	
59.7 cubic yards stone	.98774	58.97	
			250.61
Miscellaneous:			
Preparing for work		32.56	
Care of plant in service		57.49	
Steamboat service		71.50	
Administration and incidentals		95.14	
			256.69
Total			832.84

Statement for 856 linear feet of double-row dike.

Class of work, etc.	Prices of materials.	Cost of each class of work.	Total.
Sinking 215 piles:			
Labor and subsistence		$368.48	
297 bushels coal	$0.11575	34.38	
63 pounds 8-inch spikes	.0325	2.05	
6,986 linear feet piling	.08023	560.49	
			$965.40
Weaving and sinking 347 linear feet of foot mat 20.6 feet wide:			
Labor and subsistence		139.60	
48.5 cords willow brush	1.86236	90.32	
61.1 cubic yards stone	.98774	60.35	
			290.27
Miscellaneous:			
Preparing for work		70.98	
Care of plant in service		125.30	
Steamboat service		155.88	
Administration and incidentals		207.36	
			559.52
Total			1,815.19

PROCURING CONSTRUCTION MATERIALS.

During the season 836 cords of willow brush were procured by hired labor, between Pomeroy, Kans., and Parkville, Mo., at a cost of $1.86236 per cord, including the cost of the brush on the stump and loading on barges.

The brush was transported to the work on barges by the *Melusina*, an average distance of 16 miles.

Thirty-one thousand nine hundred and seventy-seven linear feet of cottonwood piling was procured, of which 27,977 linear feet was purchased and 4,000 linear feet produced by hired labor.

The average cost of piling, including the delivery and handling, was $0.08023 per linear foot.

There was also procured by purchase 8,964 linear feet of wales, at an average cost of $0.0317 per linear foot.

Three hundred and sixty-three cubic yards of stone were purchased at a cost of $0.98774 per cubic yard, inclusive of delivery and inspection.

PRESENT CONDITION OF WORKS OF IMPROVEMENT.

The works in the vicinity of Kansas City still continue in excellent condition, with the exception of the upper bank protection of the Kaw Bend revetment, for which the necessity of making the repairs approved by the Commission is now apparent.

This work will be done as soon as the stage of water becomes low enough.

A good depth of water has been maintained at Kansas City during the low-water season through the agency of the dikes constructed 2 years ago, which have caused accretions reaching, on an average, to the top of the piles.

As large masses of driftwood accumulate at the outer ends of the dikes, the effect of the latter is made to approximate that of solid dikes in causing eddies, which eat away the accretions just below their ends, and it may be necessary, in order to stop this action and preserve the dikes, to construct a revetment for a distance of about 200 feet above and below each of them.

The revetment work in Bee Creek Bend, above Fort Leavenworth, is standing the high water satisfactorily.

The revetment in Nigger Bend is reported to be in good condition.

The stream ends of the two upper dikes at Miami, constructed in June, 1890, have been undermined and washed away for a distance of about 100 feet. This action is liable to continue until woven aprons are placed around the ends of the dikes, which it was impossible to do at the time when the dikes were constructed with the funds available. The cost of protecting the Miami dikes in the manner indicated will amount to about $1,500.

SPECIAL SURVEYS.

A shore-line survey was made in July, 1890, from Miami, Mo., to a point 3 miles below the mouth of Grand River.

In September, 1890, measurements were made and soundings taken at all of the dikes, 29 in number, constructed in the Missouri River between Kansas City, Mo., and Wellington, Mo., by different railway companies, for the purpose of protecting their tracks against being washed away by the river.

In September and October, 1890, examinations were made of obstructions in the Kansas River at three bridge crossings in the vicinity of Kansas City, Kans.

Surveys were made in December, 1890, and in May, 1891, between the mouth of the Kansas River and the Hannibal and St. Joe Railroad Bridge, to determine the effect produced by the dike constructed just below the mouth of the Kansas River by the National Water Works Company of New York.

In January and February, 1891, a hydrographic survey of the bowlder and gravel reef in the Missouri River at Sibley Bridge was made.

The reef is an ancient terminal moraine, and at low stages of water constitutes a dangerous obstruction to navigation.

The survey consisted in taking about 12,000 soundings, which were located by angles. The soundings were reduced to the plane of standard low water at Sibley Bridge, and were used as a basis in preparing a plan and estimate of cost for cutting a navigable channel through the reef, under the south span of the bridge, along the right bank of the river, so as to enable water craft to pass the bridge and reef safely at all navigable stages.

A survey was made of the river between Bee Creek and Fort Leavenworth Bridge in May, 1891.

In May and June, 1891, a hydrographic survey of the Missouri River was made and borings taken in the vicinity of the proposed rectification works near the mouth

of the Osage River, to be used as a study in determining the details of the improvement works in that vicinity, for which a project was submitted under date of April 16, 1891.

Eighteen plates of tracings and two drawings, embodying the results of the above special surveys, were prepared and forwarded to your office during the past year.

The total cost of field and office work pertaining to special surveys amounted to $3,882.16.

MISSOURI RIVER WATER GAUGES.

The water gauges between Fort Leavenworth, Kans., and St. Charles, Mo., were inspected in July, August, and September, 1890, and in April and June, 1891.

The cost of this service amounted to $466.60.

CARE AND REPAIR OF PLANT.

After the suspension of construction work at Kansas City, Mo., and Miami, Mo., in June, 1890, the plant used on those works was for some time left in the river and not stored on ways, so as to be ready for service in case the river and harbor bill should pass early enough to make further work possible during that season.

The Kansas City plant was hauled out of the river and laid up on the ways at Quindaro in the latter part of November, 1890, while that at Miami was laid up in December, 1890, on ways constructed opposite and above the town during November.

In accordance with your instructions of April 29, 1891, the work of caulking and launching the fleet at the Quindaro boatyard was begun May 3. Rapid progress was hindered by delays in securing the services of a sufficient number of caulkers, who had to be engaged at distant points, and in getting the launching tackle from Miami; the work was also interfered with by rainy weather. It was completed June 12.

The launching party was immediately transfered to Miami; and the launching of plant at that point was begun June 15 and completed June 27.

The cost of care and repair of plant for the past fiscal year, including watching, constructing ways at Miami in December, 1890, laying up boats at Quindaro and Miami in November and December, 1890, launching boats at Quindaro and Miami in November and December, 1890, launching boats at Quindaro and Miami in May and June, 1891, rent of ground, administration and miscellaneous expenses, amounted to $24,185.87.

MOVING PLANT.

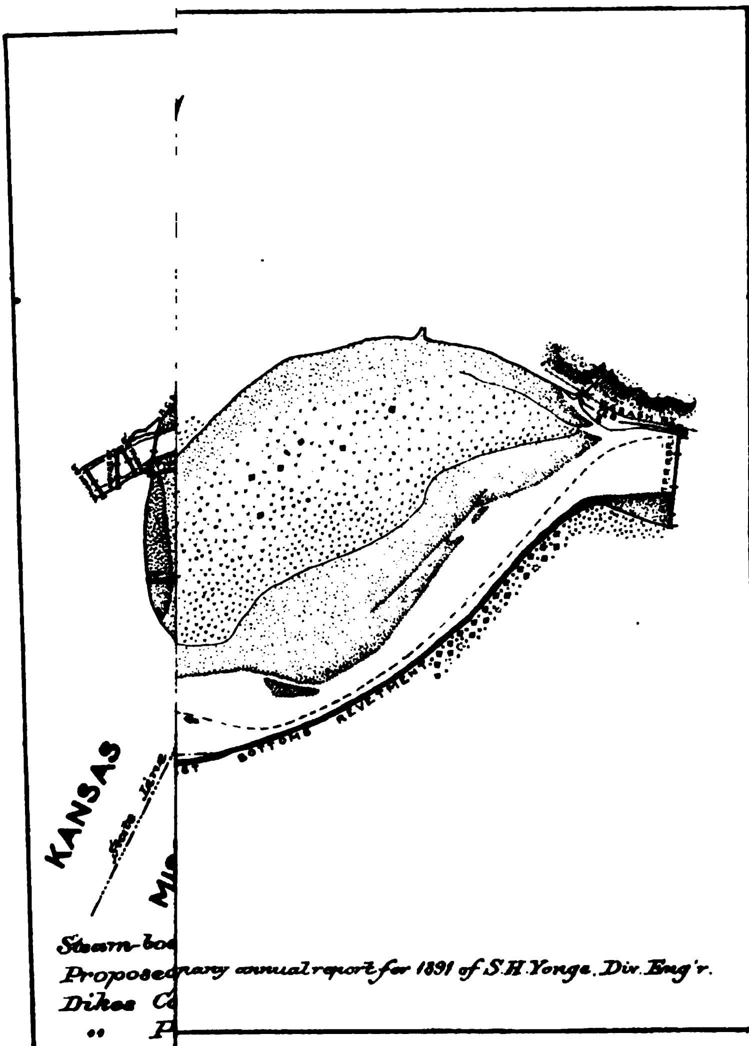
The plant which had been stored at Quindaro boatyard consisted of 44 pieces; of this number 24 pieces, *i. e.*, the steam-launch *Melusina*, 2 pile sinkers with tenders, 1 grader, 1 double-deck quarter boat, 1 single-deck quarter boat, 1 mattress boat, 11 100-foot barges, and 4 64-foot barges were left at Kansas City for service on the work to be carried on in that vicinity this season; of the remaining 20 pieces, 1 grader is to be transferred to St. Joseph Division, and 1 machine boat, 1 mattress boat, 1 hydraulic grader, 9 100-foot barges, 1 carpenter boat, 2 64-foot barges, 4 survey quarter boats, and the 17 pieces stored at Miami, *i. e.*, 1 double-deck quarter boat, 2 single-deck quarter boats, 2 pile sinkers with tenders, 6 100-foot barges, 5 64-foot barges, and the unservicable steam-launch *Doris*, are being forwarded by the towboats *Wm. Stone* and *Alert* to the mouth of the Osage River, for service on the proposed works in that vicinity. The work of moving plant is now nearly completed; its total cost to date, including the cost of bringing 4 hydraulic pile sinkers from Bushburg to the mouth of Osage River, dismantling the boatyards at Quindaro and Miami, and loading lumber, plant, and machinery on barges, administration and miscellaneous expenses, amounts to $10,448.78.

In conducting the operations of the past fiscal year I have been assisted by R. H. Bacot, A. H. Weber, and R. A. Crawford, assistant engineers, all of whom have performed their duties in a creditable manner, the two former in charge of the operations relating to plant and construction work respectively, and the latter in charge of special surveys.

Very respectfully, your obedient servant,

SAML. H. YONGE,
Division Engineer.

Lieut. Col. CHAS. R. SUTER,
Corps of Engineers, U. S. Army,
President Missouri River Commission.


KANSAS
State Line
BOTTOMS REVETMENT
Steam-boa
Proposed
Dikes
Proposed ary annual report for 1891 of S.H. Yonge, Div. Eng'r.

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APPENDIX B B B.

BRIDGING NAVIGABLE WATERS OF THE UNITED STATES.

1. Report of The Board of Engineers on proposed bridge across Hudson River at New York City.
2. Report of Board of Engineers on bridge across Chicago River at Canal Street, Chicago.

B B B 1.

REPORT OF THE BOARD OF ENGINEERS ON PROPOSED BRIDGE ACROSS HUDSON RIVER AT NEW YORK CITY.

THE BOARD OF ENGINEERS,
New York City, April 23, 1891.

GENERAL: In compliance with your indorsement dated December 4, 1890, The Board of Engineers has the honor to submit the following report on the plans of the North River Bridge Company for the construction of the bridge authorized by the act of Congress approved July 11, 1890, across the Hudson River at New York City.

The provisions of this act defining the nature of the structure and the responsibility devolved upon the Secretary of War in relation thereto are the following:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That authorization is hereby given to Jordan L. Mott, John King McLanahan, James Andrews, Thomas F. Ryan, Garrett A. Hobart, F. W. Roebling, Charles J. Canda, Edward F. C. Young, Henry Flad, Gustav Lindenthal, A. G. Dickinson, John H. Miller, William Brookfield, Samuel Rea, William F. Shunk, Philip E. Chapin, and their associates, as a corporation as hereinafter provided, to locate, build, maintain, equip, and operate a bridge, proper approaches thereto and terminals, appurtenances and works connected therewith, across the Hudson River in and between the city of New York, in the State of New York, and the State of New Jersey, and to lay tracks thereon for the connection of the railroads on either side of said river, in order to facilitate interstate commerce in the transportation of persons and property, and for vehicle, pedestrian, postal, military, and other purposes: *Provided*, That said bridge shall have not less than six railroad tracks with a capacity for four additional tracks for future enlargement, and shall be constructed with a single span over the entire river between the towers, located between the shore and the established pierhead lines in either State, and at an elevation above the river not less than that of the existing Brooklyn suspension bridge over the East River, and which elevation may be increased by the Secretary of War as hereinafter provided, and that no pier or other obstruction to navigation either of a temporary or permanent character shall be constructed in the river between said towers.

SEC. 2. That the construction of said bridge shall be commenced within three years after the passage of this act, and shall be completed within ten years after the commencement of construction. But that the Secretary of War is hereby authorized to

extend the time for the commencement of construction for two additional years upon cause shown by the company, and provided that the Secretary of War shall deem such cause sufficient and satisfactory; and that if the company fail to commence the construction of said bridge within the time so extended this act shall be null and void. And the company at least three months previous to commencing the erection of said bridge shall submit to the Secretary of War a plan of the bridge, with a detailed map of the river at the proposed site of the bridge, and for the distance of one-half of a mile above and below the site, with such other information as the Secretary of War may require for a full and satisfactory understanding of the subject. And the Secretary of War may upon receiving said plans and map and other information, order a hearing before a board of engineers, appointed by him for taking testimony of persons interested in railroads and navigation, relative to the clear height of the superstructure above ordinary high water. Such clear height shall not be less than that named in section one of this act, and the Secretary of War may thereupon order such additional clear height as he shall deem necessary for the security of navigation. And he is hereby authorized and directed upon being satisfied that a bridge built on such plan and at said locality will conform to the conditions of this act to notify the said company that he approves the plans therefor; whereupon said company may proceed to the erection of said bridge. But until the Secretary of War approve the plan and location of said bridge the erection of the same shall not be commenced; and should any change be made in the plan of the bridge during the progress of the work thereon, such change shall likewise be subject to the approval of the Secretary of War.

As will be seen by the appended papers,* marked "A" to "I," the Board has endeavored to procure, by all available means, such testimony as would assist in a thorough examination and study of the subject. Every effort was made to secure at the public hearings the attendance or representation of all parties in interest, including the municipal authorities of the cities of New York and Hoboken. These hearings were extensively advertised, and for the final one eighty-eight special invitations were sent out. At the first public hearing the officials representing the cities of New York and Hoboken joined in asking a delay of 30 days, with a view to submitting written statements relative to the proposed bridge at the expiration of that time. Accordingly, the Board took an adjournment; but neither at the adjourned meeting nor subsequently have the expected documents been received, although the Board has repeatedly invited the attention of the authorities of both cities to the matter.

As appears in the sections quoted above, the act authorizing this bridge requires that before erection shall begin the Secretary of War shall approve the plans and location, and may order such additional clear height above the water way as he shall deem necessary for the security of navigation. To these matters the Board has limited its inquiries.

PLANS AND SITE.

The plans presented by the bridge corporation are complete, so far as regards the requirements for such plans under the act, except that no provision is made for the passage of vehicles other than rail cars or for pedestrians to pass beyond the anchorages; and that no detailed information is given in regard to approaches and terminals, although asked for at the public hearing. The bridge shown on the drawings is simply a railroad suspension structure limited by the anchorages which it is proposed to erect at Twenty-third street and Tenth avenue, New York City, and at Twelfth and Bloomfield streets, Hoboken. Whether such a structure does or does not meet the requirements of the act is a legal question upon which the Board ventures no opinion.

*Not printed.

CLEAR HEADWAY.

The question of minimum clear headway to meet the reasonable demands of commerce will now be considered.

This clear headway is fixed by the act at "not less than that of the existing Brooklyn Suspension Bridge," which was established by the Secretary of War at 135 feet in the clear, above mean high water of the spring tides, at the center of the main span, and which was so built; its height at the piers is 118 feet.

Whether this clear headway of 135 feet above mean high water of the spring tides forms a safe standard for a bridge to be erected across the North River at Twenty-third street, New York City, demands careful consideration.

East River has a comparatively narrow and crooked channel, obstructed by shoals and islands, and having at some points currents so strong (about four knots) as to render navigation difficult. North River affords a wide and straight channel free from obstructions and navigable even in moderate fogs. Here is now situated the commercial center of the port. Above the city the North River opens a navigable and much navigated route to Albany and all intermediate points, which has always been jealously protected against obstruction. No commercial anchorage ground is allowed between Ellis Island and Fourteenth street, Hoboken, or Thirty-fifth street, New York. Throughout the entire distance of 145 miles to Albany the river is spanned by only one bridge, at Poughkeepsie, and this has a clear headway of 160 feet at three spans, each about 520 feet wide, one central and one near each bank. At present the North River tonnage exceeds 18,000,000 tons, which is larger than that of any other river of the United States, the Detroit and St. Clair rivers excepted; and surveys are in progress looking to extending a navigable depth of 20 feet to the head of navigation at Troy.

In a word, the commercial interests centering at and above the site of this proposed bridge are very great; and to hamper commerce here by a bridge structure too low to meet its full requirements, present and prospective, would prove far more injurious to the port of New York than could possibly be the case on East River. Too narrow draw spans may be widened to meet increased demands, but the clear headway of such a suspension bridge as is here proposed is more permanent than the natural reefs at Hell Gate.

That the East River Bridge has to a certain extent hampered commerce and depreciated wharf property above its site, appears to be generally conceded, although to what extent is not easily determined. At the date when its height was established (1869) a height of 135 feet appeared sufficient to reasonably accommodate the shipping of the period. The Brooklyn Bridge Commission states:

> An addition of 5 to 10 feet to the present height [the Secretary of War did add 5 feet to this height], would permit almost every vessel submerged to half load line, advantage being taken of the time of tide, to pass with topgallants standing. The light spars only above the topgallant would be sent down.

Would this height be accepted to-day, even for East River?

It has been stoutly argued before the Board that actual experience with the East River Bridge has proved the contrary, and that the structure has seriously depreciated the value of wharf property above its site by diverting traffic to the lower Brooklyn water front. That some effect of this kind may reasonably be expected seems probable, since a virtual tax is laid upon large vessels by compelling them to lower their spars at a cost ranging from $75 to $200 in riggers' bills, in-

creased by a detention under expenses of from 1 to 4 days. The fact is patent to all that commerce has largely shifted its early location from along the New York side of East River to other parts of the harbor; but causes other than bridge obstruction have been at work, and it is not possible to assign its true weight to each. Insufficient clear headway for the larger class of modern vessels is doubtless one important cause.

The cost of from $75 to $200, exclusive of detentions for lowering the upper masts of large vessels passing the bridge, may not seem a large amount to sacrifice. But the results will be much more serious than this cost. Even such charges as those will prevent vessels going to wharves above the bridge, if they can find a place elsewhere. The proposed bridge at Twenty-third street, like the Brooklyn Bridge, will gradually exclude larger sailing vessels from going above it. New York is seriously suffering to-day from lack of sufficient dock front, and this bridge will be one more obstacle in the way of properly using its North River front above Twenty-third street for a great commerce.

Another and more precise mode of arriving at an estimate of the minimum safe height for the proposed North River Bridge, is to critically compare the dimensions of the shipping now engaged in the commerce of the port with similar data collected when the East River Bridge plans were approved. Such a comparison has been made, and a considerable increase of tonnage and height of spars is indicated.

The Bridge Commission of 1869 was furnished by the Ship Owners' Association with data respecting 18 vessels to represent then existing commerce; on this list no schooner and only 8 ships exceeded 446 tons. Appended to this report is a list* of 42 schooners, all exceeding 500 tons and averaging 656 tons, the largest being 1,096 tons, which were docked above Twenty-third street on North River between June 1 and September 1, 1890. Of these 15 had trucks over 135 feet above the light-draft line, and 19 had trucks between 130 and 135 feet above this level. There is also appended a list* of 15 large schooners which entered the port of New York during the year 1890, 6 of them delivering coal near Forty-second street, North River. Only one of the list had trucks less than 135 feet above the light-draft line; the average of the whole 15 was 150 feet, the maximum being 168 feet above this line. But this comparison of mast height only partially represents the rapid development of the demands of modern shipping in the matter of clear headway. In 1869 nearly all large sailing vessels were square rigged, with several comparatively light upper spars which could be easily lowered. To-day schooners have largely usurped their place, and their masts are composed of only 2 sticks, the topmast being a massive spar, which requires the appliances of a professional rigger to ship and unship.

To complete the comparison between the sailing vessels of 1869 and 1890, a list of 11 representative ships now trading at the port of New York is appended.* The height of truck ranges from 153 to 191½ feet above the light-draft line; and two of them, the *Falkland* and *Pinmore*, could not pass light under the Brooklyn Bridge even by lowering their spars because their jigger masts consist of single sticks, rising 153 feet and 139 feet respectively above the light-draft line. Five of them carry over 2,000 tons and two, built last year, over 3,000 tons.

These facts and figures confirm what was stated orally before the Board at the public hearings, that the size of sailing vessels is increasing, and that a clear headway which was sufficient in 1869 is no longer so to-day.

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* Not printed.

This view is sustained by the formal action of the Maritime Association of the Port of New York, which by its board of directors unanimously adopted the following resolution at a meeting held on March 11, 1891:

Resolved, That the Board of Directors of the Maritime Association of the Port of New York, interested in maintaining the commerce of the port, after careful consideration, strongly urge that no bridge be permitted over the North or East River of less height than 150 feet in the clear above high water in mid-channel, believing that any bridge of less height will be a serious detriment to the commercial and material interests of the port by obstructing channels of navigation and trade.

The replies to the circular letter addressed to ship owners and builders interested in the commerce of the port, and appended to this report,* are to the same effect. Out of 14 replies, recommending what the writers regard as a suitable clear headway for the proposed North River Bridge, two suggest 145 feet; three, 150 feet; two, 155 feet; two, 160 feet; one, from 155 to 160 feet; two, 165 feet; one, from 165 to 170 feet; and one, 192 feet.

In considering the question of clear headway, one important difference between the two bridges must not be overlooked. Owing to the greater length of the cables, variations in temperature will produce greater changes in the clear headway of the North River Bridge than occur at the Brooklyn Bridge. Mr. Lindenthal calculates the total difference of level at the middle of the suspended structure due to these variations to be 9 feet, as against 5½ feet of the Brooklyn Bridge. He has rightly taken this element into account in his plans providing for a height of 135 feet; and this must be done in deciding what the authorized height should be.

APPROACHES AND TERMINALS.

There are certain requirements implied in the act which the Board thinks any bridge of this character should possess, and which are not met by the plans presented; they refer to the bridge approaches and terminals, and are submitted for such consideration as the language of the law allows. Thus the act requires that the proposed bridge shall have "proper approaches thereto and terminals, appurtenances, and works connected therewith," and the Board thinks that such provision naturally requires that it should be practicable to operate railroad lines over the bridge with the safety and efficiency demanded at a terminal which is to accommodate the many railway systems which will desire to use it. This special condition of safe operation is recognized by Mr. Lindenthal, the chief engineer of the corporation, in his statement:

The rigidity of the bridge is expected to be such that trains on all tracks may run at express speed, which is a vital condition for the use of the bridge by the respective railroads to be accommodated, and for the fullest accommodation and convenience of the traveling public.

Yet grades are projected which, for a short distance on the bridge itself, and on the whole of its New York approach, offer the same difficulties as are found on the Pennsylvania Railroad where it crosses the Allegheny Mountains. Such grades involve the necessity of pushing engines, with all their attendant delays. Moreover, when the tracks are wet or ice-covered there will be a possible danger of runaway trains in making the descent to the terminal station. To present this point fully it is necessary to refer to a few figures.

* Not printed.

The proposed location of the New York station, given in Mr. Lindenthal's report of March 13, 1891, is on Sixth avenue, above Twenty-fourth street, where the level of the track will be the same as that of the Sixth avenue elevated road, or 60 feet above mean high water (20 feet above ground). Thence to the bridge tower the ascent is 72 feet in 4,000 feet, or at a grade of 95 feet per mile. The descent on the New Jersey side between the tower and the anchorage is somewhat less abrupt, being on a grade of 74 feet to the mile; and it is understood that the same grade will continue to the station, but the exact location of this station is withheld by the corporation. These figures refer to the tracks located on the lower deck of the bridge; the 6 tracks of the upper deck will rise 25 feet higher, and Mr. Lindenthal, without naming the grades, states that—

Even a steeper grade than 1.8 per cent. (95 feet per mile) will be necessary to accomplish it.

These very objectionable grades are commented upon adversely in all the letters from railroad officials and experts presented by the corporation to sustain the claim that no increase of bridge height over the minimum prescribed in the act should be required. The following extracts from these letters convey a fair idea of their general tenor:

Mr. S. M. Prevost, general superintendent of transportation of the Pennsylvania Railroad, writes:

It seems to me that such a heavy grade as this (95 feet per mile) will very seriously impair the usefulness of the bridge and very materially interfere with the adoption of the bridge route by the railway companies reaching Jersey City.

I suppose you are aware that this grade is equivalent to the grade on the Pennsylvania Railroad between Altoona and Gallitzin, and you know that over that distance we are obliged to use two engines for an ordinary passenger train in ascending the grade, and you are also probably aware of the great care with which these trains are handled when descending the grade and when arriving at Altoona station; therefore with such a grade over your new Hudson River Bridge you should have the same difficulties in getting out of New York, and the same difficulties in getting in into it as we have over the Allegheny Mountains.

Mr. Paul S. King, chief engineer Lehigh Valley Railroad Company, writes:

One other thing that should not be overlooked is the danger of trains going down grade from the bridge to the station at the foot of the grade. In this case the location of the station at the foot of the grade can not be avoided. The more urgency is there to protect the station against runaway trains. To keep a train going down a steep grade under control is not always possible. The state of the weather and the nature of the traffic can not be controlled.

Mr. Theodore N. Ely, general superintendent of motive power of the Pennsylvania Railroad, writes:

The grade, 1.8 per cent., which you mention as having been accepted by your company, I should regard as excessive; it will certainly greatly increase the difficulties of operation, and during bad weather I feel confident that there will be serious delays to trains, unless ample allowance is made on the time tables for the distance covered by the grade.

Other quotations to the same effect might easily be made, as may be seen by reference to the original letters, appended* and marked "H."

RECOMMENDATIONS.

After giving the attention to this matter which its importance demands, the Board would hesitate to recommend the approval of the unmodified plans under any circumstances. If railroad transit is im-

*Not printed.

peratively demanded in this immediate vicinity and a bridge of no greater height than 135 feet is financially possible, the crossing should be sought through one or more tunnels, or by moving the site about 8 miles up the river to the vicinity of Fort Washington, where high ground exists, admitting greater headway and making easier grades possible, and where the river width is not materially greater than at Twenty-third street. So long a detour is doubtless objectionable, but if a height greater than 135 feet is impossible at Twenty-third street, a change of site is an alternative.

The Board is of opinion that a bridge of 135 feet height at Twenty-third street is an "unreasonable obstruction to navigation." The Board therefore recommends that the clear headway at the middle of the span above high water of spring tides be increased in the plans to not less than 150 feet under any conditions of load or temperature, and at the towers to not less than 140 feet. These figures correspond to a clear headway of 155 feet at the center of the span at the mean temperature of 60° F.

Respectfully submitted.

HENRY L. ABBOT,
Colonel of Engineers, Bvt. Brig. Genl., U. S. A.,
President of the Board.

C. B. COMSTOCK,
Colonel of Engineers, Bvt. Brig. Genl., U. S. A.

D. C. HOUSTON,
Colonel of Engineers.

G. L. GILLESPIE,
Lieutenant-Colonel of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

[First indorsement.]

OFFICE CHIEF OF ENGINEERS,
U. S. ARMY,
April 27, 1891.

Respectfully submitted to the Secretary of War.

The Board of Engineers at New York, to which was referred, for consideration and report, the plans submitted by the North River Bridge Company for bridge across Hudson River between New York City and New Jersey, under provisions of act of Congress approved July 11, 1890, states that after giving the attention to this matter which its importance demands, it would hesitate to recommend the approval of the unmodified plans under any circumstances, and that if railroad transit is imperatively demanded in this immediate vicinity and a bridge of no greater height than 135 feet is financially possible, the crossing should be sought through one or more tunnels, or by moving the site about 8 miles up the river to the vicinity of Fort Washington, where high ground exists, admitting greater headway and making easier grades possible, and where the river width is not materially greater than at Twenty-third street, the site proposed by the bridge company. So long a detour is doubtless objectionable, but if a height greater than 135 feet is impossible at Twenty-third street, a change of site is an alternative.

The Board is of opinion that a bridge of 135 feet height at Twenty-third street is an "unreasonable obstruction to navigation," and it therefore recommends that the clear headway at the middle of the span above high water of spring tides be increased in the plans to not less

than 150 feet under any conditions of load or temperature, and at the towers to not less than 140 feet. These figures correspond to a clear headway of 155 feet at the center of the span at the mean temperature of 60° F.

The views and recommendations of the Board are concurred in by this office and are recommended for approval.

It is also recommended that a copy of the report of the Board be furnished the bridge company for its information.

H. M. ADAMS,
Major, Corps of Engineers, in charge.

[Second indorsement.]

WAR DEPARTMENT,
April 29, 1891.

The views and recommendations of The Board of Engineers, as concurred in by the officer in charge of the office of the Chief of Engineers, are approved.

A copy of the report of the Board will be furnished the bridge company as recommended.

L. A. GRANT,
Acting Secretary of War.

LIST OF PAPERS* APPENDED TO THE REPORT OF THE BOARD OF ENGINEERS ON THE NORTH RIVER BRIDGE, DATED APRIL 23, 1891.

A. Stenographic report of an interview with Mr. Gustav Lindenthal, chief engineer of the North River Bridge Company, on December 19, 1890.

B. Stenographic report of the public hearing of the Board on January 8, 1891.

C. Stenographic report of the public hearing of the Board on February 27, 1891.

D. Copy of a circular letter of January 12, 1891, addressed to ship owners by Lieut. Col. G. L. Gillespie, Corps of Engineers, asking for information relative to height of masts of schooners, and requesting their views as to whether a bridge 135 feet high, above Twenty-third street, New York City, would interfere with or injuriously modify the present or future navigation of the Hudson River. The replies received, forty-two in number, are also herewith, accompanied by a tabulated abstract of their contents.

E. A report made to Colonel Gillespie by Mr. G. W. Kuehnle, assistant engineer, in regard to vessels of over 500 tons that were at the wharves and docks on the Hudson River above Twenty-third street, New York City, during June, July, and August, 1890. With this report are (1) a list of such vessels; (2) a list of large ships trading at the port of New York, and (3) a list of large schooners in the port of New York.

F. A letter of March 10, 1891, with four inclosures, from Mr. Edward Hincken relative to the cost of raising and lowering masts of schooners passing under the Brooklyn Bridge. Mr. Hincken is a member of the board of pilot commissioners of New York, and represented that body as well as the Maritime Association of New York before the Board.

G. Formal resolution of the Maritime Association of the port of New York, dated March 11, 1891, against the construction of any bridge over the East and North Rivers having a clear height of less than 150 feet.

H. Supplementary statement on the capacity of the proposed bridge and the clea height of the same, made by Mr. Lindenthal on March 13, 1891. This is accompanie by ten communications received by him from railroad officials on the influence whic the proposed height would have on the grades and railroad traffic over the bridg Appended thereto is also a letter from Mr. Lindenthal, dated March 21, 1891, reques ing that that part of his statement of March 13 which speaks of the silence of th Maritime Association on the question of height be stricken out.

I. Some considerations on the question of the building of the North River Bridg by Charles Donohue, counsel for the North River Bridge Company, dated March : 1891.

* Not printed.

B B B 2.

REPORT OF BOARD OF ENGINEERS ON BRIDGE ACROSS CHICAGO RIVER AT CANAL STREET, CHICAGO.

Report of the Board of Engineers, convened by Special Orders No. 39, Headquarters, Corps of Engineers, June 17, 1891, in the matter of the Canal Street Bridge, Chicago, as called for by indorsement from the office of the Chief of Engineers, U. S. Army, dated June 17, 1891.

The facts with relation to this matter are fully set forth in the accompanying papers,* including both those originally referred to the Board for the purpose of investigation and those subsequently received, all of which are forwarded with this report.

A brief résumé of the data of record is as follows: The Chicago River, including the main stream and the two branches, was originally but a shallow and sluggish bayou, receiving the seepage and drainage from the flat region traversed by it, and upon which the city of Chicago is built.

The river is the Inner Harbor of Chicago, and practically the only one since the Lake Shore, with the exception of a restricted area, adjacent to the mouth, which is protected by piers built by the General Government, is occupied by railways and city parks, and the Outer Harbor, inclosed by the breakwaters built in the lake, is not used for commercial purposes by reason of the absence of wharves and facilities for the transfer and handling of freights. The banks of the river traversing the heart of the city were therefore by degrees bulkheaded and improved for business purposes, and the stream was dredged to permit movement of loaded vessels, until at this time vessels of the heaviest lake tonnage discharges and receive freight at points several miles from the lake, which formerly could be reached only in a rowboat. At the same time, with the development of the commercial uses of the stream, which have attained dimensions commensurate with the unexampled growth of the city in general, the river was made a main or trunk sewer, receiving the discharges from all lateral sewers intercepted by it, and by suitable means at the head of the South Branch provision has been made for reversing the movement of the stream so as to discharge its contents to the west and south instead of into the lake, whence the water supply of the city is taken.

To provide for land traffic across the river bridges have been built at numerous points, and these have multiplied as the rapidly increasing population made urgent demand for better means of transit.

The better examples of these bridges are fairly well designed for their purpose, being built on a center pier, with a draw opening on each side, having altitude above the water sufficient to permit the passage of tugs and small steam vessels beneath them, and being swung rapidly by steam, admit of an alternation of land and water traffic, with brief intervals of suspension for one or the other. Many of the bridges, however, are low and must be swung even for a tug, and others have but one draw opening, the other being closed or insufficient for passage of vessels.

In addition to the obstruction to navigation due to the presence of the bridge is that due to the loading and discharging of vessels lying at wharves contiguous to the bridge, which in many cases by the restriction of the water way amounts to a total blockade of the river until

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* Not printed.

the obstructing vessel moves. Having in view the hundreds of vessels movements and the tens of thousands of land transits required for the daily service of the city, it is evident that the situation is one of great difficulty, and calls for the most careful adaptation of means to ends that a just balance be maintained between the conflicting requirements of land and water traffic.

The Canal Street Bridge was authorized by an ordinance of council with the object of creating means of transit at a point not conveniently reached by the bridges above and below. As the bridge would be of no service unless approachable from both directions, it was necessary to condemn lands for street purposes at both ends, and the obstructions to accomplishing this and of assessing benefits upon adjacent property were such that, to expedite matters, the bridge was put under construction in advance of the opening of the connecting streets and the projected widening of the river on the southeast bank. The original intention was to build a high bridge, but as this would have necessitated elevated approaches, the plan was changed and a low bridge substituted. With this exception the general design of the bridge is not specially objectionable. It was, as in other cases, to have a center pier, with navigation spans of over 60 feet width on each side, but as actually constructed the defects are serious. The bridge stands at the north end of a sharp turn in the stream, which is now but 124 feet wide between banks. Of this the pivot pier and protection occupies 37 feet, leaving 68 feet opening on its northwest side and but 19 feet on the southeast side. Furthermore, the protection wings to the pivot pier, with a total length of nearly 270 feet, extend into the bend south of the bridge, so that a large vessel requires for passage every inch of space, and in swinging for the turn has to scrape the banks at stem and stern, while touching the protection wing on the side. If in these circumstances the wharves on the northwest side of the river are occupied by vessels discharging at the lumber yards the blockade is manifestly total.

The situation is one that from the navigation point of view can not be relieved until at least the southeast draw is opened to its full width by the condemnation and removal of the strip of land some 450 feet in length and 43 feet in width at the widest portion.

From the point of view of the land traffic the existing conditions are still less favorable. The pivot pier was hastily built on piles which apparently do not reach hard bottom, as the bridge has already been raised two or three times in the attempt to make it serviceable for transit. At the present time it is considerably out of line and level and will only close sufficiently to permit a casual foot passenger to cross. For wheel traffic it is useless, and would be in any event, as the approaches are blocked at both ends. The bridge is therefore practically of no service whatever.

These facts, it may be stated, are generally admitted, and the objections made on the part of the property owners concerned in the construction of the bridge, and who have contributed money towards its cost and that of condemnation, to the removal of the obstruction to navigation until such time as the full width of water way in both draws could be secured, are apparently based upon an apprehension that if the present structure, notwithstanding its uselessness to them and its obstructive features, be removed, they will never get another.

The navigation interests concerned are fully set forth in the accompanying papers (Schedules B, C, D, E, and F).* They are manifestly of

* Not printed.

enormous magnitude, and a few hours of delay and obstruction at the bridge cost the business of Chicago as much as did the bridge itself. The pressure for freight facilities in the crowded river is constantly upward, and the dimensions of the vessels engaged in lake traffic are steadily increasing, so that the objections to obstructions increase in a geometrical ratio from year to year.

The actual amount of land traffic concerned is somewhat a matter of speculation. At the present time, as has been stated, there is none at all. The area to be immediately benefited is somewhat restricted, and to gather in the 100,000 or 200,000 people supposed to be interested necessitates taking account of the population of wards quite remote from the locality. There are bridges in the vicinity, viz, at Eighteenth and Twenty-second streets, within one-fourth and one-fifth mile, respectively, of the Canal Street Bridge, which can be and are now used. At the same time the matter is complicated by the necessity referred to by the commissioner of public works of the temporary closing of the Halstead Street Bridge, which is the main north and south thoroughfare, which would involve embarrassment if there were no other to take its place meanwhile. On the other hand, the full utilization of the Canal Street Bridge will require the construction of viaducts for crossing the railway tracks multiplying in the vicinity, and this will take both time and money.

On the whole it does not appear that there was any such urgent necessity for the bridge as to warrant its construction in advance of the creation of proper facilities for the movement of vessels, and it is evident that an egregious municipal blunder was made in so building it as to create vexatious and unnecessary obstruction to navigation, while at the same time the structure was perfectly useless to those for whose benefit and partly at whose cost it was erected.

The situation is fairly well summed up in the communication from the commissioner of public works to the city council, which is embodied in the minutes of the Board on page 5, to which attention is invited and from which the following is quoted as substantially in accordance with the views of the Board:

* * * * * * *

The present condition of the bridge is such that it can not be entirely closed. The piles on which the pier rests have settled 5¼ inches, and are still settling, and the pier has tilted to the south, throwing both ends of the bridge out of line. There is but one channel through the bridge, which is on the north side. The land adjoining the river on the north and both sides of Canal street is used for lumber yards, and when vessels are unloading at the docks large vessels can not pass through the draw.

In its present condition the bridge is a serious obstruction to navigation, causing much delay to the large class of vessels passing this point, and is of no use whatever for team traffic, and can only be made so by entirely removing the present superstructure and rebuilding the pier, which should be of masonry to maintain the superstructure in working order.

* * * * * * *

CONCLUSIONS.

First. The water traffic at the Canal Street Bridge is of immense extent and value, and is rapidly increasing. The land traffic at present does not exist, and its future, in view of the surrounding complications, is problematical.

Second. In general character the bridge should either leave the water way unobstructed for a clear width of not less than 100 feet, properly adjusted with reference to the banks, or should have two draw openings of not less than 60 feet each with a clearance of 14 feet above Chicago

datum (or 12 feet above mean lake level) for passage of tugs and scows, and be maneuvered by steam.

In view of the difficulties attending the construction of elevated approaches and the fact that other low bridges exist, the requirement as to clearance may be waived.

Third. The existing structure is useless for land traffic and is an unreasonable obstruction to navigation in the following respects:

a. It has but one draw opening, and that on the concave side of the river.

b. It has but $7\frac{1}{2}$ feet clearance, so that it must be swung for every tug.

c. Lying in a bend the navigable width for long vessels is reduced to about 45 feet, so that with a vessel lying at an adjacent wharf passage is entirely blocked.

d. The pivot pier is improperly constructed and does not support the bridge.

e. The bridge has no provision for swinging otherwise than by hand, which is too slow a process in the circumstances.

Fourth. The changes necessary to remove the unreasonable obstructive features are:

a. To land the bridge and take out the present pivot pier, preliminary to rebuilding it in a proper manner.

b. Before undertaking the reconstruction of the pivot pier to complete the construction of the water way of the south draw to its full width by the needful widening of the river along the south bank.

c. Swing the bridge by steam.

d. The clearance or height above water should be 14 feet, but this requirement would probably indefinitely delay the reconstruction, and is perhaps not absolutely essential.

Fifth. The time required to make the necessary changes is:

a. To land the bridge and remove the defective pile pivot pier—2 weeks.

b. To reconstruct the bridge, supposing the water ways to have been opened and no other than engineering difficulties to be considered—90 days.

RECOMMENDATIONS.

That notice be made to the city of Chicago:

First. To remove the present pivot pier, the protection wings or bridge rests, and all other adjuncts to the existing construction now standing in the stream and obstructing navigation, within 3 weeks from date of service of notice.

Second. To postpone any further construction of the bridge as now designed until such time as the river shall have been so widened as to provide for the full opening of the south draw.

Third. That provision be made when the bridge is restored for maneuvering it by steam power.

All of which is respectfully submitted.

WILLIAM LUDLOW,
Major, Corps of Engineers, Bvt. Lieut. Col., U. S. A.
CHAS. E. L. B. DAVIS,
Major, Corps of Engineers,
W. L. MARSHALL,
Capt., Corps of Engineers.

APPENDIX C C C.

OCCUPANCY OF AND INJURY TO PUBLIC WORKS BY CORPORATIONS AND INDIVIDUALS.

[Reported under section 2, river and harbor act of 1884, and section 4, river and harbor act of 1886.]

1. Report of Lieut. Col. G. L. Gillespie, Corps of Engineers.
2. Report of Col. Wm. P. Craighill, Corps of Engineers.
3. Report of Capt. H. S. Taber, Corps of Engineers.
4. Report of Col. O. M. Poe, Corps of Engineers.
5. Report of Maj. Amos Stickney, Corps of Engineers.
6. Report of Lieut. Col. W. H. H. Benyaurd, Corps of Engineers.

(1) REPORT OF LIEUTENANT-COLONEL G. L. GILLESPIE, CORPS OF ENGINEERS.

The only instances of piers or other structures built by the United States which are occupied by corporations or individuals, referred to in the act of August 5, 1886, are found in the Upper Hudson River. Some of the piers so occupied have been given in previous reports.

During the fiscal year ending June 30, 1891, the following revocable licenses have been granted by the Secretary of War:

1. *Clark & Laurence*, October 20, 1890, to enter upon, occupy, and use as an ice-house dock, 157 feet 7 inches of the *Government dike on Bogart Island*, in the Hudson River, New York.
2. *Best & Carman*, September 6, 1890, to occupy and use as an ice-house dock, 258 feet of *Campbell Island Dike*, Hudson River, New York.
3. *The Knickerbocker Ice Company*, September 6, 1890, to enter upon, occupy, and use as an ice-house dock, 281 feet of *Beacon Island Dike*, Hudson River, New York.
4. *The Knickerbocker Ice Company*, September 25, 1890, to occupy and use as an ice-house dock, 190 feet of *Bogart Island Dike*, Hudson River, New York.
5. *The Knickerbocker Ice Company*, September 25, 1890, to occupy and use as an ice-house dock, 322 feet of *Cabbage Island Dike*, Hudson River, New York.
6. *John N. Briggs*, April 16, 1891, to occupy and use as an ice-house dock, 450 feet of *Coeyman Dike*, Hudson River, New York.

G. L. GILLESPIE,
Lieut. Col., Corps of Engineers.

(2) REPORT OF COLONEL WM. P. CRAIGHILL, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Baltimore, Md., July 1, 1891.

GENERAL: In compliance with the requirements of General Orders 6 and 7, series of 1887, and 9 of 1888, from Headquarters, Corps of Engineers, I have the honor to report concerning the rivers and harbors in my charge that no additional information on the subjects of those orders has been received by me since the last Annual Report, with the following exceptions:

Certain information has been received concerning the ice piers near the mouth of the Great Kanawha River. Complaint was made by Mr. John Armstrong, of Point Pleasant, that the Kanawha and Ohio Railway (now the Kanawha and Michigan), or the lessees, were filling up the river at or near the right shore below the Government ice piers at Point Pleasant in connection with the operation of a tie hoist on the railroad company's land.

The lower ice pier on that side is opposite the lower line of the railroad company's land. The company own the land from this up to, and for some distance above, the upper ice pier.

Assistant Engineer Scott went to see the situation on the 12th June, 1890, and reported as follows:

This tie hoist has been in operation but a few months, but there was already a considerable material, such as raft strappings, bark, and sunken ties, close along the shore and in the edge of the water. No material change has been yet effected, but it is evident that unless considerable pains is taken to take care of this refuse the depth along the shore, both at the hoist and for some distance below, will be materially reduced by the operation of it.

It can in no case affect the navigation of the river. It may, however, and Mr. Armstrong claims it will, reduce the depth along the shore enough to interfere with the usefulness of the ice harbor.

I have recently talked with the receiver of the railroad company, Mr. Robert W. Kelly, about the matter. He says it is the purpose of the company to attend to this; to keep the tie refuse out of the river, and not to let their landing or front get filled up by it. It is plain, however, that up to this time it has not been attended to properly.

It appears from the papers forwarded to you from Washington with the letter of May 31, 1890, from the Office of the Chief of Engineers, that the railroad company did not join with the other land owners in the agreement of September 9, 1884, in reference to the use of river front during seasons of ice. (See Colonel Merrill's letter of September 22, 1884, to the Chief of Engineers.) It would seem, however, that this has little if any bearing on the case in hand.

A petition has recently been circulated (at Mr. Armstrong's instance, I understand) addressed to you in reference to this matter, which has been quite extensively signed by river men. This petition will probably be submitted to you soon.

I will add that Mr. Armstrong owns or is interested in the land immediately below that of the railroad company, which makes him, of course, particularly interested in this matter, as filling up to any considerable extent along the shore in front of the company's land would naturally shoal the water along his front.

The last information relative to the hoists, etc., is contained in the following extract from a recent letter of Mr. Scott:

The hoists are still operated in about the same way as previously reported, and Mr. John Armstrong, or Armstrong Brothers, still complains of them. I called the attention of the United States grand jury to the operation of these hoists at the last term of the United States court, held here last month, stating that Armstrong Brothers had made complaint about them to this office. I understand, though I am not positively informed about it, that indictments were found against the parties who are operating the hoists, viz, the Ohio River Railroad Company and the Kanawha and Michigan Railroad Company.

I should, probably, in this connection, refer to the action of the United States grand jury at the last term here in the matter of cribs, breakwaters, coal tipples, etc., mainly connected with and located at the various coal works on the river, under the court's construction of the law of September 19, 1890.

Indictments were returned against all parties or corporations on the river who have any cribs, breakwaters, or tipples, on the ground that nothing of this kind can be built or permitted to stand in the river without special permission of the Secretary of War, whether they interfere with the free and safe navigation of the river or not.

I was summoned before the grand jury on this matter and took considerable pains to state clearly that no complaints had been made to the office about any of these structures; that such cribs and tipples were absolutely necessary for the loading and holding of coal, and that I did not consider that any of them obstructed or impaired navigation.

The custom of this office heretofore in reference to such cribs and tipples has been to give the parties owning or proposing them the best information and advice at hand in regard to their location or construction, but always to make it clearly understood that if they got them in the way of navigation of any kind or where they ever became the subject of complaint by navigators the Government would take prompt steps against the owners and to have the obstruction torn out. There has, as you are informed, been no trouble with this plan. I believe it is every way preferable to the one now contemplated under the construction that seems to be put on the new law.

Relative to the Elk River the following is the situation concerning the bridges, dams, and booms previously reported on.

No change of importance has taken place or been made in any of them for several years, and they remain practically in the same condition concerning navigation as reported on page 1599 of Report, Chief of Engineers, 1886. Referring particularly to the several low mill dams in the river, I will add that nothing has been done towards the abatement or removal of any of them under the law of February 24, 1887 (Report of Chief of Engineers, 1887, pages 1923 and 1924).

In reference to the boom built at Sutton last year by the Elk Island Boom Company and the lawsuit concerning it with the Elk River Boom Company (owners of the old boom near Charleston), I have recently been informed that the suit was decided in favor of the Elk River Company at the last term of the United States court.

The decision is that the act under which the Elk Island Company's boom was built was unconstitutional on account of privileges before granted to the Elk River Boom Company. Nothing has been yet done, however, towards altering or removing the boom itself and it continues to be the subject of complaint, as reported last year, of sawmill men, etc., operating below it.

A number of indictments were returned against parties on Elk River owning cribs, booms, etc., by the United States grand jury at the recent term of the court under the river and harbor act of September 19, 1890, but I have not learned, except in two or three cases, what works were aimed at. No action has been taken yet, so far as I am informed, on the indictments.

Very respectfully, your obedient servant,

WM. P. CRAIGHILL,
Colonel, Corps of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

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(3) REPORT OF CAPTAIN H. S. TABER, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Little Rock, Ark., July 1, 1891.

GENERAL: In accordance with the requirements of General Orders No. 9, Headquarters, Corps of Engineers, U. S. Army, Washington, D. C., dated June 6, 1888, I have the honor to state that there are in this

district no piers, breakwaters, locks, dams, or other structures or works built or made in the United States, in aid of commerce or navigation, that are used, occupied, or injured by a corporation or an individual, except that the Black River, from Poplar Bluff, Mo., to Corning, Ark., has been more or less obstructed by the carelessness of loggers in not making up their rafts properly, and also the dam on Black River, a few miles below Poplar Bluff, has been torn out without doubt by the use of dynamite, as various shattered logs belonging to the dam have been found. I have been unable to ascertain who the offending parties are.

* * * * * * *

The question of the obstruction of improved rivers by small rafts of logs, numbering perhaps from half a dozen to a dozen logs, which are allowed to drift at will without guard, and sink now and then, is becoming a serious one and should perhaps form a part of this report, as they amount to an injury to public improvements, although they do not come under the law as it is now worded, and is in some instances of so serious a nature as to practically nullify the thorough work of the snag boat for one whole season. The snag boat removes the stumps and snags from the channel, and their places are promptly taken by these logs, which are, in some cases, worse to handle and remove than the snags. Some steps should be taken to fix a penalty for sending rafts down improved rivers without guard that is as severe and sure in its action as the penalty imposed upon a railroad for obstructing the river with a bridge, as I believe that just at the present time all the bridges together reported in this letter do not hamper navigation one-fifth as much as the sunken rafts and logs.

I am, sir, very respectfully, your obedient servant,

H. S. TABER,
Captain of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

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(4) REPORT OF COLONEL O. M. POE, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., July 30, 1891.

GENERAL: In accordance with section 4 of the river and harbor act of August 5, 1886, and General Orders, No. 9, Headquarters, Corps of Engineers, June 26, 1888, I have the honor to report the following cases where "piers, breakwaters, etc.," under my charge "have been used, occupied, or injured by a corporation or individual" during the fiscal year ending June 30, 1891.

OCCUPANCY OF PUBLIC LANDS, ETC., BELONGING TO THE RESERVATION OF ST. MARYS FALLS CANAL, MICHIGAN.

First. By the commissioners of the board of water works of the village of Sault Ste. Marie, Mich., by a 24-inch inlet supply pipe passing through the south canal pier near the head of the canal. The authority for this occupation is a "revocable license," granted by Secretary of War William C. Endicott, on the 8th day of December, 1885, and accepted by the commissioners of the board of water works on the 23d day of November, 1885.

Second. By the commissioners of the board of water works of the village of Sault Ste. Marie, Mich., by water mains for the use of said village, along the following-described line, to wit: Beginning at a point in the north line of Portage street, not to exceed 25 feet distant westerly along the north line of Portage street, from the east line of said canal reservation, and extending northerly on a line not to exceed 25 feet distant westerly from said east line to a point not to exceed 200 feet from the north line of said Portage street. The authority for this occupation is a "revocable license" granted by Secretary of War William C. Endicott on the 31st day of July, 1886, and accepted by the commissioners of the board of water works on the 15th day of July, 1886.

Third. By the Sault Ste. Marie Bridge Company by a railroad bridge across the St. Marys River and St. Marys Falls Canal at the rapids of St. Marys River. Authority was granted by an act of Congress approved July 8, 1882, to said bridge company to construct a bridge across St. Marys River at or near the rapids of said river in Chippewa County, Mich., for the use of railroads whose business crosses or will cross the river at said locality and whose lines of road now or may hereafter approach the river at that place. The right of way was approved in an instrument executed by Secretary of War William C. Endicott on the 2d day of August, 1887, and the said right of way was accepted by the Sault Ste. Marie Bridge Company by James McMillan, its president (no date).

Fourth. By the Edison Sault Light and Power Company by a line of wire cable across St. Marys Falls Canal near the foot of Magazine street, and connecting their power-house (situated on the rapids of the St. Marys River) with the city of Sault Ste. Marie, Mich. The authority for this occupation is a "revocable license" to the Edison Sault Light and Power Company to lay a wire cable across the St. Marys Falls Canal and the grounds thereof at the rapids of the St. Marys River, in the State of Michigan, granted by Secretary of War William C. Endicott on the 2d day of April, 1888, which instrument was also executed by the Edison Sault Light and Power Company by B. B. Powell, secretary and manager, thereunto lawfully authorized, on the 31st day of March, 1888.

Fifth. By the Edison Sault Light and Power Company by a dam from the main land to Island No. 3, in the rapids of the St. Marys River. The authority for this occupation is a "revocable license" to the Edison Sault Light and Power Company, a corporation existing under the laws of the State of Michigan to erect and maintain a dam on the rapids of the St. Marys River between the mainland and Island No. 3, granted by Secretary of War Redfield Proctor on the 14th day of March, 1889. The license was accepted by said company by C. E. Ainsworth, president, and E. S. B. Sutton, secretary, on the 5th day of March, 1889.

Sixth. By the city of Sault Ste. Marie, Mich., by a sewer outlet through the south pier of St. Marys Falls Canal, Michigan, at the foot of River street. The authority for the occupation of this property is a "revocable license" to the city of Sault Ste. Marie, a municipal corporation existing under the laws of the State of Michigan, to make a sewer outlet through the United States canal pier at the foot of River street, in said city, granted by Secretary of War Redfield Prector on the 4th day of September, 1889, and accepted on the part of the city by Mayor Otto Fowle on the 21st day of August, 1889.

Seventh. By the city of Sault Ste. Marie, Mich., by underground connection with St. Marys Falls Canal, through an intake pipe connected

with the city sewerage system and used for flushing the city sewers. The authority for this occupation is a "revocable license" to the city of Sault Ste. Marie, a municipal corporation existing under the laws of the State of Michigan, to make a connection with the St. Marys Falls Ship Canal above the locks for the purpose of obtaining an intake through which water may be drawn from the canal to flush the city sewers of said city, but for no other purpose whatsoever, granted by Secretary of War Redfield Proctor on the 19th day of December, 1889, and accepted by said city by Mayor Otto Fowle on the 10th day of December, 1889.

Eighth. By the city of Sault Ste. Marie, Mich., a portion of the canal grounds known as "Douglass street," extending from Portage avenue to the inclosure of the canal grounds on the north side of Water street in said city. The authority for this occupation is a "revocable license" to the city of Sault Ste. Marie, Mich., a municipal corporation existing under the laws of the State of Michigan "to enter upon that part of the land of the United States forming a part of the canal grounds which is marked 'Douglass street' on a map attached thereto, for the following purposes only: To grade and pave the same; to lay water and sewer pipes and side and cross walks; to place street lights; to maintain said improvements in good order and repair, and to use said land for the purposes of a highway," granted by Secretary of War Redfield Proctor on the 17th day of July, 1890, and accepted by Mayor Otto Fowle and Recorder M. F. McDonald, on behalf of said city, on the 2d day of July, 1890.

Ninth. By the Canadian Pacific Railway Company, by the occupation of a floor space 4 feet by 6 feet in dimensions in the public room of the office building of the St. Marys Falls Canal for the purpose of maintaining a branch telegraph office. The authority for this occupation is a "revocable license" to the Canadian Pacific Railway Company to occupy said floor space for the purpose named, granted by Acting Secretary of War L. A. Grant on the 28th day of October, 1890, which instrument was also executed by the Canadian Pacific Railway Company by Superintendent James Kent, Canadian Pacific Railway's Telegraph, on the 23d day of October, 1890.

Tenth. By the Western Union Telegraph Company, by the occupation of a floor space 4 feet by 6 feet in dimensions, in the northwest corner of the public room of the office building of the St. Marys Falls Canal, on the north side of the lock of 1881, at Sault Ste. Marie, Mich., for the purpose of maintaining a branch telegraph office. The authority for this occupation is a "revocable license" to the Western Union Telegraph Company to occupy said floor space for the purpose named, granted by Acting Secretary of War L. A. Grant on the 4th day of May, 1891, which instrument was also executed by the Western Union Telegraph Company, by Vice President Thos. T. Eckert and Secretary A. R. Brewer, on the 16th day of April, 1891.

Eleventh. By the city of Sault Ste. Marie, Mich., by a storm-water sewer outlet through the south pier of St. Marys Falls Canal, Michigan, at the foot of River street. The authority for the occupation of this property is a "revocable license" to the city of Sault Ste. Marie, a municipal corporation existing under the laws of the State of Michigan, to make, maintain, and use said sewer outlet as shown on attached plans, granted by Assistant Secretary of War L. A. Grant on the 11th day of June, 1891, and accepted by said city by Mayor George W. Brown on the 26th day of May, 1891.

Twelfth. By Edward O-shaw-a-no, Island No. 5 in the Rapids of St. Marys River, as a dwelling place. No authority for this occupation.

Proceedings to evict said O-shaw-a-no were instituted and in July, 1890, the case was decided in favor of the United States. The defendant has by law 3 years, or until July, 1893, in which to pay costs and take a new trial, and it is understood that he proposes to do this.

LANDS OCCUPIED BY U. S. LIGHT-HOUSE ESTABLISHMENT.

The United States Light-House Establishment occupies as site for light-keeper's dwelling a portion of the St. Marys Falls Canal grounds 100 feet by 200 feet extending from the south bank of the canal to Canal street in the city of Sault Ste. Marie, Mich., and just west of the principal meridian of Michigan; the authority for this occupation being a letter of Secretary of War William C. Endicott, dated March 25, 1885, and being terminable at pleasure of the War Department; also the extreme end of the southwest canal pier, by a light-house, and a portion of the northwest pier by a range light; authority by act of Congress, dated March 3, 1879.

The United States Light-House Establishment also occupies the lower and upper ends of the west pier of the St. Clair Flats Ship Canal by light-houses. Authority by acts of Congress dated July 28, 1866, and March 3, 1871; also the breakwater at harbor of refuge at Sand Beach, Mich., by lights on the east and west side of the north entrance, a light on the south side of the east entrance, and a light inside of the harbor on a separate crib near the north side of the east entrance. The lights on the breakwater were originally erected and maintained by the Engineer Department and transferred to the Light-House Establishment under authority from the Secretary of War, dated April 18, 1885; also a light on the north pier at the mouth of the Au Sable River, Michigan. Authority by acts of Congress dated June 10, 1872, and March 3, 1873.

INJURIES TO PIERS, ETC., OF ST. MARYS-FALLS CANAL, MICHIGAN.

On June 6, 1891, the steamer *W. H. Gratwick*, bound down, while being placed in position in the lock, through a mistake of the engineer in answering signals, ran into the lower gate, striking the north leaf about 4 feet from the miter post, burying her stem into the pine fender of the upper girder, and crushing the sheathing for the width of the stem and for about 6 feet vertically. Fortunately the blow was received in a strong part of the leaf, otherwise very serious damage might have occurred. As it is, the life of the gate was shortened by the blow. A bill for $30, the estimated cost of repairs, was sent to the owner, Mr. W. H. Gratwick, of Buffalo, N. Y., and was duly paid and deposited to the credit of the Treasurer of the United States.

On June 14, 1891, the steamer *E. C. Pope*, bound up, ran into the west end of the Merchants' Dock, adjoining the canal pier, and broke some of the superstructure timbers of the pier. A bill for $44.76, the estimated cost of repairs, was presented to the owners, the Dry Dock Navigation Company, Mr. Gilbert McMillan, secretary, but so far the amount has not been paid.

INJURY TO PIERS, ETC., PERTAINING TO SAGINAW RIVER IMPROVEMENT, MICHIGAN.

On July 29, 1890, a fire broke out in the lumber yards in the vicinity of the Carrollton revetment, extended to various mills, etc., and wrought great destruction. Among other structures the revetment suffered

severely. Over 2,000 linear feet of superstructure were destroyed, leaving but 2 to 3 feet of piling above water, and reducing somewhat the height of the filling of slabs, stone, and clay. Three fire tugs assisted in checking the flames, $294 being paid for their services.

On November 25, 1890, another fire broke out in the revetment, but was promptly extinguished before much damage was done, $16 being paid for the services of a fire tug. The estimated cost of repairing the damage done by these two fires is $6,000.

INJURY TO PIERS, ETC., OF ST. CLAIR FLATS CANAL, MICHIGAN.

On May 18, 1891, the steam barge *Glengarry*, being disabled and in tow of the tug *Onaping*, ran into the end of the west pier and did $50 damage. A bill for this amount was sent to the owners, the Montreal Transportation Company, and was promply paid and deposited to the credit of the Treasurer of the United States.

No further use, occupation, or injury to works in my charge than those above reported are known to have occurred during the fiscal year ending June 30, 1891.

Very respectfully, your obedient servant,

O. M. POE,
Colonel, Corps of Engineers,
Bvt. Brig. General, U. S. A.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

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(5) REPORT OF MAJOR AMOS STICKNEY, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
Buffalo, N. Y., July 9, 1891.

GENERAL: I have the honor to report the cases in which piers, breakwaters, lock and dams, or other structures or works built or made by the United States in aid of commerce or navigation, which were used, occupied, or injured, by a corporation or an individual, and extent and mode of such use, occupation, or injury in the district under my charge, during the fiscal year ending June 30, 1891, as follows:

The north pier, harbor at Buffalo, N. Y., is occupied by the Delaware, Lackawanna and Western Railway Company. It is covered with trestlework for handling coal. This occupation was by license of the Secretary of War up to February 20, 1891, on which date the license was revoked. The occupation has continued since the revocation of the license and still continues. It is understood that the Department of Justice now has the matter in hand.

Very respectfully, your obedient servant,

AMOS STICKNEY,
Major of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

(6) REPORT OF LIEUTENANT-COLONEL W. H. H. BENYAURD, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., July 1, 1891.

GENERAL: I have the honor to report that there are no cases within my district in which works built or made by the United States in aid of commerce or navigation are occupied by corporations or individuals other than that reported in my letter to the Department of March 25, 1891, in regard to the occupation of the levee at Old Town, Cal., by the Southern California Railway.

Very respectfully, your obedient servant,

W. H. H. BENYAURD,
Lieut. Colonel, Corps of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

LETTER OF LIEUTENANT-COLONEL W. H. H. BENYAURD, CORPS OF ENGINEERS.

UNITED STATES ENGINEER OFFICE,
San Francisco, Cal., March 25, 1891.

GENERAL: I have the honor to present the following report upon the occupation by the Southern California Railway Company of the levee built by the Government at Old Town, Cal., as called for by your indorsement on the letter of Britton & Gray herewith.

The levee in question was built by the Government in 1876 for the purpose of diverting the San Diego River, and causing it to flow into False Bay instead of San Diego Bay, which was being injured by the detritus brought down in flood stages. It extends from Presidio Hill to the northerly end of Point Loma, and is in length about 7,700 feet. The land upon which it is built is the property of the Government. As shown on the enclosed tracing,* marked B, the Southern California Railway Company has (without authority) taken possession of about 1,100 feet of the easterly end of the levee by a spur running from its main line. It is not an absolute necessity that the levee should be used in order to reach the pumping works (situated still further to the eastward) as the spur could leave the main track at a point further south than it does at present and only cut the levee near its easterly end. The occupation of the stretch of levee in question is, however, a decided convenience to the railroad company.

The levee is strongly built (being 23 feet thick on top and heavily revetted with stone on the river slope), and has withstood the floods of the San Diego River without injury for 15 years, and while such occupation may be of advantage to the levee, in causing the railroad company to care for it and the road in case of threatened danger, it is considered that the structure is sufficiently strong to withstand floods. Small appropriations are made by the Government from time to time, and are expended in keeping the stone revetment and levee in good condition.

The question, however, is not as to the advantage or disadvantage of the occupation of the levee by the railroad company, but whether such

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* Not printed.

occupation is in violation of section 9 of the river and harbor act of September 19, 1890. Considering that such was the case, the attention of the officials managing the road was called to that fact, with request that steps be taken to vacate the levee. While section 11 of the act requires the proceedings to be conducted through the Law Department of the Government, it was decided to communicate first with the railroad officials, which was done. The company desired to enter into some agreement by which the tracks could be allowed to remain upon the levee, with the understanding that the latter should be kept in good condition, which request I had no authority to grant.

The levee was built and is maintained simply for the purpose of preventing the San Diego River from returning to its former bed near Old Town, and emptying into San Diego Bay. Its usefulness is not destroyed nor impaired by the tracks of the railroad company being laid upon it.

I see no objection to allowing the railroad company to occupy that portion of the levee in question, with the understanding that it shall be kept in good condition, and shall be vacated when desired by the Government.

Very respectfully, your obedient servant,

W. H. H. BENYAURD,
Lieutenant-Colonel, Corps of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

APPENDIX D D D.

MAINTENANCE AND REPAIRS OF WASHINGTON AQUEDUCT—WATER SUPPLY, DISTRICT OF COLUMBIA—INCREASING THE WATER SUPPLY OF WASHINGTON, DISTRICT OF COLUMBIA—ERECTION OF FISHWAYS AT GREAT FALLS.

REPORT OF LIEUTENANT COLONEL GEORGE H. ELLIOT, CORPS OF ENGINEERS, OFFICER IN CHARGE, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

1. Washington Aqueduct.
2. Water supply, District of Columbia.
3. Increasing the water supply of Washington, D. C.
4. Erection of fishways at Great Falls.

OFFICE OF THE WASHINGTON AQUEDUCT,
Washington, D. C., July 9, 1891.

GENERAL: I have the honor to transmit herewith report of operations for the following works in my charge for the fiscal year ending June 30, 1891, viz:

Washington Aqueduct.
Water supply, District of Columbia.
Increasing the water supply of Washington, D. C.
Erection of fishways at Great Falls.

Very respectfully, your obedient servant.

GEORGE H. ELLIOT,
Lieutenant Colonel of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

D D D 1.

WASHINGTON AQUEDUCT.

Appropriations for the Washington Aqueduct are applied to the improvement, the maintenance, and repair of those portions of the Washington water supply, other than the tunnel, that have been placed under the supervision of the Chief of Engineers. The works include the masonry dam, 2,877 feet long, extending from the Maryland to the Virginia shore at Great Falls of the Potomac, 14 miles west of Washington;

the works at Great Falls for regulating the supply to the conduit; the conduit from Great Falls, 9 feet in diameter; the 3 reservoirs; viz, the receiving reservoir, about 4½ miles from the city; the distributing reservoir, about 2 miles west of the city; and the high-service reservoir in Georgetown for the supply of the higher portions of that city; the mains by which the water is carried from the reservoirs and delivered into the city's distributing system, and the bridges for supporting the mains across Rock Creek.

The work of repairing the damage to the dam at Great Falls done in the great flood of June 2, 1889, was completed early in the year. The flood carried away the 15-inch coping course and part of the next lower course, from a total length of 1,103 feet or 347 feet from the dam across the Maryland channel, and 756 feet from the dam across the Virginia channel. The work of repair commenced June 6, 1889, and, as the condition of the river would allow (except after the end of the last fiscal year while waiting for the new appropriation), it was steadily and energetically carried on under the supervision of Thomas Sullivan, the watchman gate-keeper of the division, who, as on other occasions of need, showed excellent talent as a foreman. By means of divers, all of the coping except 16 pieces was recovered from the deep water below the dam. On account of the destruction of the Chesapeake and Ohio Canal in the same flood, it was impossible to replace the lost pieces, except by taking a portion of the coping from the Virginia end of the dam, and from the portion of the dam that crosses Conns Island (in both of which places the dam is not so much exposed in time of floods), and replacing it with concrete. In the original construction of the dam the coping bolts were too short and without heads, and this was the cause of the disaster. The replaced coping is fastened in place by bolts 5 feet long with heads, and split, and driven on wedges. The cost of repair was about $9,000.

Early in July I found that I was not able to keep the water in the distributing reservoir up to its proper height, and it was evident that there was something wrong in the conduit, either in the feeder at its head or in one of the numerous tunnels along its route. I had an examination made at the former place, and the river being exceptionally low, there was head room in the conduit sufficient to enable the watchman to pass through it in a boat lowered down to the water in the gate house, from the gate house to the inlet from the river. It was found to be about half full of deposits (logs, stumps, gravel, and mud), that must have gotten in in the flood just mentioned. The upper portion of the conduit was drained by putting down the stop timbers above the mouth of the inlet from the river, and raising those of the waste below the mouth. The water in the reservoirs was held back by putting down the stop timbers at the "north connection" of the receiving reservoir. The work of cleaning out the feeder of the conduit was started at 10 o'clock a. m. on the 21st of July, and carried on with a force of 32 men without stopping until 12 oclock noon of the 22d. Everything had then been removed, except about 6 inches of very soft material, and this was gotten rid of by flushing the conduit by letting water in from the river and wasting it at waste weir No. 1. The length of the feeder, or the distance cleaned out, was 272 feet, The depth of the deposit was from 3 to 6 feet. The heaviest part of it was about 15 feet in from the mouth of the feeder. It was about 6 feet in depth for a distance of about 15 feet and composed of mud, sand, sticks, and roots packed solidly. Just at the mouth of the feeder was found an old locust stump about 2 feet in diameter, the roots of which spread out to a diameter of 10 feet. In

the gate house was found a log about 2 feet in diameter and about 6 feet long. While the water was drawn from the conduit I had the conduit carefully inspected from the gate house to culvert No. 2, a distance of 9,300 feet. From 6 inches to 8 inches of sediment was found at the bottom of the conduit, but no obstruction except a telegraph pole about 20 feet long, which was found below waste weir No. 1. This and the débris found in the feeder to the conduit were doubtless drawn in from the river during the flood of 1889, and they show the danger to which the head of the conduit is subject in such floods.

On the 12th of September, when the water was turned on the 12-inch main between the reservoir and Foundry Branch, which main had been used as a drain during the construction of the 48-inch auxiliary connection, there was found to be almost a complete stoppage of the flow between the reservoir and Foundry Branch. The water was at once shut completely off between Foundry Branch and the reservoir, and the high service reservoir in Georgetown was supplied from the cross connection from the 30-inch main at Foundry Branch. On making an examination of the main there was found to be some small obstructions just above the blow-off at Foundry Branch, which were removed, but their removal did not relieve the main. Repeated emptyings and fillings of the main and every expedient that could be thought of were used to locate and remove the difficulty, but it was December before I could obtain the full flow of the main. The obstruction, if it was solid, may have passed out into Foundry Branch through the blow-off at night, or at some other time when it was not seen, or, as a portion of this part of the main is above the hydraulic mean gradient, it may have been an accumulation of air.

The numerous trees growing over and near the conduit between Great Falls and the receiving reservoir, especially between the former and the "Club House," endangered the conduit by the penetration of their roots into the joints of the arch. A notable example of this danger was found when the upper portion of the conduit was drained and examined at the time of the cleaning out of the feeder to the conduit at Great Falls. I therefore caused all of these trees to be cut down, saving the trunks of such as were suitable for posts for use in fencing the aqueduct lands.

A brick storehouse 40 feet by 20 feet in area has been constructed at the distributing reservoir for the storage of tools and materials for repairs on that division of the aqueduct, and it is proposed, during the next fiscal year, to erect a similar one at Great Falls for the upper division. The old office building at the receiving reservoir has been put in repair to serve the same purpose on the receiving reservoir division.

Strong guard fences have been built on the sides of the Conduit road at the dam at the receiving reservoir and at the high embankments at the culverts and other places between the distributing reservoir and the receiving reservoir. These were made necessary by the great increase of travel on the Conduit road and the danger of accidents, especially at night. Four thousand two hundred and sixty-six feet of these fences were built during the fiscal year, and it is proposed during the next fiscal year, as funds will allow, to protect the embankments farther up the line.

The road between the "Club House" and Great Falls is the only route of communication with the falls, but it is almost impassable in winter. It does not follow the line of the conduit, but it was constructed for aqueduct purposes and is owned by the United States. With the coöperation of the farmers, who also use the road, I have macadamized a length of 1,548 feet and a width of 10 feet on the worst

portion of the road, and hope to be able to improve more of it during the next fiscal year.

There being no place inside the gate house at Great Falls where the height of water could be measured, I have uncovered manhole No. 1, which is about 450 feet below the gate house; removed the stone-slab cover; carried up the wall of the manhole to the surface of the ground (7 feet 8 inches from the crown of the arch), and have placed on the manhole an iron cover, through which, by means of a rod graduated with reference to the top of the dam (148), the height of water can be measured and reported every morning with the other reports and at any other times desired.

A new "curtain" screen for the screen house at the distributing reservoir was completed during the year. It is of copper wire, ⅜-inch mesh, in two sections, 39 feet long by 13 feet 3 inches wide each, which pass over a drum supported on the floor of the screen house. It is balanced by counter weights and is operated without difficulty by the watchman and one assistant.

In August a survey was made of the lands owned by the United States between Foundry Branch and the distributing reservoir. There was found to be five cases where parties owning the adjoining land have built fences on the lands of the United States, and five cases where private improvements were found to encroach on these lands, and a report was made thereon. I have recently obtained your authority to employ the District surveyor to make an accurate survey of the lands surrounding the receiving reservoir. The survey has been completed and the lines will be permanently marked. During the next fiscal year it is proposed to continue the surveys of the lines of the aqueduct lands and to place boundary stones at all the angles where they are missing.

With the approval of the Secretary of War, I have turned over to the Commissioners of the District of Columbia, for care and maintenance, 131 valves which were placed on the outlets from the 48-inch main and the connecting mains recently laid under the act of March 2, 1889, for controlling the supply of water from these mains to the District's distributing mains. The other valves on the former mains, 98 in number, consisting of main valves, blow-off valves, large air valves, vacuum valves, and small constant air valves, in addition to the valves on the old mains, remain under the care of this office.

A contract has been made for the delivery of five iron pillar cranes for handling the stop timbers on the line of the aqueduct, viz, one at the cut through the cross dam at the distributing reservoir, one at the influent and one at the effluent chamber of the receiving reservoir, one at the intake of the conduit at Great Falls, and one at the waste into the river from the forebay at the same place. Some of these stop timbers are 16 feet long and 1 foot square, and without machinery they require so many men to lift them when watersoaked that in case of sudden requirement of their use at night serious consequences are liable to result from delay in procuring assistance.

The opening from conduit tunnel No. 1 at waste weir No. 1, near the head of the conduit, one of the most important of the waste weirs, is exposed to an inflow from the river in great floods like that of June, 1889, when the river rose 75 feet at this point, and to an indraft of logs and other driftwood, which endangers the conduit and the supply of water to the city. The valve, a butterfly valve, set in the masonry of the weir, leaks and should be replaced or repaired. It was intended to make the required repairs and alterations at this place during the

last fiscal year, but as it is impossible to get materials for the purpose to the weir, except by the Chesapeake and Ohio Canal, the work has been postponed until the next fiscal year, when, it is expected, the canal will again be in operation.

There is a leak in the conduit at the upper end of Cabin John Bridge. I have had it measured repeatedly, and it does not now seem to be increasing, but, although it is not large (it is about 40,000 gallons a day), it may in time, if allowed to continue, undermine the conduit. In order to repair it the conduit will have to be emptied the entire distance from Great Falls to the receiving reservoir, and I propose at the time of the repair to take advantage of the opportunity and have the interior of the conduit inspected from one end to the other. On account of the coldness, earlier, of the water that will remain in the tunnels through which the men will have to wade, and for the reason, also, that the conduit can not be emptied until the repairs of the Chesapeake and Ohio Canal, which are now in progress, are completed, neither the repairs of the conduit nor the inspection can probably be made before August or September.

The tar pavement of the roadway over Cabin John Bridge is badly worn in holes, which I have had filled with gravel. The travel over the bridge is very great, and I have tried to get the contractors for such pavements to resurface the bridge, but they have been too busy in the city and my work is too far from town. I have therefore come to the conclusion to pave the bridge with granite blocks which, in order not to reduce too much the rather small height of the parapets, will be of shallower depth than used for street work.

I have recently obtained the details of a patented device for tapping with taps, up to 12 inches in diameter, large mains under pressure; that is, the shutting off of the water which is always a source of anxiety on account of the danger in case of fire in the district supplied by the main, can be avoided when the main is tapped. In my report for the last fiscal year I mentioned a great deficiency of air valves and blow-offs on the old mains, which I hope to supply during the next fiscal year by the use of this device.

In the act of August 6, 1890, making appropriations for the Washington Aqueduct, the sum of $4,000 was appropriated for the purchase of 5 acres of land near the distributing reservoir, and $1,500 was appropriated for the improvement of this land. Pursuant to the approval of the Chief of Engineers, I wrote to the trustees of the owners of the land asking the price at which they would sell, and was informed in reply that $3,000 per acre was their lowest price. When I made the report of December 26, 1889, on which the appropriation was based, I had been informed that land in the vicinity had recently been sold for $600 an acre, and stated that I did not believe that a jury of condemnation would assess the value of this land at more than $800 an acre, if as much, but the success of the owners of the Glen Echo property this side of Cabin John Bridge very much inflated afterwards the asking prices of all the land everywhere along the Conduit Road. I reported the result of my correspondence to the Chief of Engineers and stated the improbability of obtaining the land by condemnation at any price within the amount of the appropriation. Fortunately the "Drovers' Rest Cattle Market" has been discontinued and all of the buildings and fences have been removed, so that the necessity of the purchase no longer exists, although it would be desirable for the United States to own the entire frontage on the northerly side of the Conduit Road opposite the distributing reservoir.

Ninety shade trees, alternate lindens and tulip trees, kindly furnished for the purpose by Colonel Ernst, Commissioner of Public Buildings and Grounds, were planted on the Conduit Road opposite the distributing reservoir and in the grounds of this reservoir. All of them not inside the fences were protected by tree boxes.

There have been no breaks or any serious leaks in any of the mains during the last fiscal year. On the M street iron aqueduct bridge there have been small "weepings" from the joints of the 48-inch main and also at a few other points, but they have in every case been readily stopped in a few minutes by the aqueduct machinist. In order to provide for the expansion and contraction of the bridge, its eastern end was made a movable end, sliding on an iron plate set on the abutment of the bridge, but the main itself can not adapt itself to changes of temperature except as is allowed by the lead joints of the main, and this doubtless accounts for the small leaks that, at extreme temperatures, are observed in the portions of the main supported by the bridge. Being under the north sidewalk of the M Street highway bridge, the main is always in shade and is favorably situated in respect of changes in the temperature of the air, so that in fact the temperature of the iron of the main is mainly governed by the temperature of the water passing through the main, and, as I have found by several experiments, it is always about the same as that of the water in the distributing reservoir.

I found the bank of Rock Creek wearing so much under the action of the 20-inch blow-off from the 48-inch main which passes out through the west wing wall of the M street highway bridge, that it would endanger the foundation of the wall, and I constructed a large flume of lumber to carry the outflow from the blow-off to the creek. It serves the purpose temporarily, but it will be necessary to extend the pipe outlet from the blow-off to the edge of the creek, and it is proposed to do this in the next fiscal year.

The construction of the cable railway of the Washington and Georgetown Railway Company on M street, Georgetown, has made it necessary to remove the arches of two of the three valve chambers which occupy nearly the full width of the street between Twenty-ninth and Thirtieth streets, and replace them by I beams and arches of small span and rise. The work has been done at the expense of the railway company under my supervision.

Last year, when the water in the river was at its low stage, or between 6 inches and 1 foot over the dam at Great Falls (which it was for several months), I found that I could not keep the water in the distributing reservoir up to its proper height of 146 feet above datum. I find the same this year, and that when the water in the distributing reservoir is lowered about 2½ feet during each of the monthly measurements of the consumption and waste of water in the city, it requires about four days to get the water in the reservoir back again to its height. The reason of this is, that *the height of the dam at Great Falls is not sufficient at low stages of the river to keep the conduit full at its head, or to enable it to deliver as much water as is now consumed and wasted in the city, and at the same time to keep up the head in the mains at the distributing reservoir to 146 feet above datum, which is necessary for the supply by gravity of the high northern portions of the city and of Capitol Hill.* The only remedy for this (and it is one that should be made before any further steps are taken for increasing the supply from the distributing reservoir to the city) is the raising of the dam at Great Falls nearly if not quite 2½ feet, or to the height of 150½ feet above datum.

On reference from the Chief of Engineers the following reports on applications to Congress for charters for railways have been made during the fiscal year:

1. Washington and Georgetown Railroad, S. 4,594, Fifty-first Congress, second session.
2. Georgetown and Arlington Railway, S. 695, Fifty-first Congress, second session.
3. Washington and Arlington Railway, S. 3,770, Fifty-first Congress, second session.
4. Washington and Chesapeake Railroad, S. 4,621, Fifty-first Congress, second session.
5. East and West Washington Traction Railroad, S. 5,097, Fifty-first Congress, second session.
6. Metropolitan Southern Railroad, S. 4,119, Fifty-first Congress, first session; two reports.
7. Rock Creek Railway, H. R. 13,191, Fifty-first Congress, second session.
8. Washington and Great Falls Electric Railway, H. R. 13,402, Fifty-first Congress, second session; two reports.

During the past year, in addition to the work that has been specifically mentioned, the usual operations for maintaining and preserving the aqueduct have been carried on. The mains have been flushed, the valves oiled and cleaned, the gate-keeper's houses have been repaired, the gates adjusted so as to preserve the water in the distributing reservoir at as high a level as possible, the dams and embankments wherever they have been washed or cut by rains have been repaired, the gutters and culverts along the line of the conduit have been kept in order, and about 907 running feet of gutters have been paved.

Iron covers and frames have been placed over the valve chambers on the line of the old mains between Twenty-eighth and Twenty-ninth streets, Georgetown, in place of wooden covers and frames. A timber trestle for use in handling stop timbers has been erected in the influent gate-house at the distributing reservoir. The highway bridge over the waste channel from the receiving reservoir has been repaired. The bank of the Chesapeake and Ohio Canal at Great Falls has been repaired, so as to prevent the drainage from houses in the village from entering the river above the mouth of the conduit and polluting the water entering the conduit. The air valve on the arched pipes of the 30-inch main crossing College Pond has been replaced by a new valve. A retaining wall about 250 feet long has been constructed along the east side of the Conduit Road, opposite the auxiliary gate-house, and the road has been widened at this point. A well 29 feet deep has been dug near the gate-keeper's house at the distributing reservoir and walled with stone, the upper 8 feet being laid in cement mortar. All the drift logs and other débris from the flood of 1889, that was liable to be drawn into the conduit at Waste-weir No. 1, near Great Falls, in any similar flood, has been removed. The deposits on the bed of the river at Great Falls, just above the intake of the conduit, which if not removed limit the supply to the conduit, have been removed. This is proper work for a dredge boat, but I have none and have to get along with long-handled shovels and scoops and forks the best way I can. Anticipating that during the low water of the coming summer there would be requirement for it, recesses have been cut in the arch at the gate-house at Great Falls, so that two additional gates can be opened. When the arch was built many years since it prevented the raising of one gate at each end of the series of ten gates that open from the river into the conduit. The outbuildings at the gate-keeper's houses, the fences around the reservoirs, and the interior of the valve chambers have been whitewashed, and the sand and other deposits in the culverts under the Conduit Road have been removed. All of these cul-

verts, on which the safety of the conduit greatly depends, have been frequently inspected and are in good order, except that the weight of the high embankments at Culverts Nos. 7, 14, and 15 has caused cracks in their arches, but they do not seem to be increasing, and they are not dangerous.

Measurements of the consumption and waste of water in the city have as a rule been made annually in June. They were taken outside the influent gate-house at the distributing reservoir by noting on an ordinary staff gauge the fall of the water in the reservoir during 24 hours, the supply to the reservoir from Great Falls in the mean time being suspended. In August last I commenced to make these measurements monthly on one of the last days of the month, and placed inside the effluent gate-house of the same reservoir a floating staff gauge graduated to hundredths of a foot, by the use of which errors in measuring the height of water caused by wind waves are avoided (there is in each vertical inch about 1,120,000 gallons of water), and the observer is sheltered from the weather during the measurement. In the table appended to this report will be found the details of the measurement of water consumed and wasted in the 24 hours ending June 25, 1891, the monthly measurements during the last fiscal year, and the annual measurements in June of each year from 1874 to 1891, both inclusive.

It will be observed that the daily midwinter and midsummer consumption and waste are about equal, and are each about 2,000,000 gallons more than the average for the year ending June 30, 1891. This average is 36,588,629 gallons, or about 1,000,000 gallons more than the measurement in 1890, which was taken soon after the 48-inch main was completed and put in operation. The average annual increase before the introduction of the 48-inch main (or from 1874 to 1889) was about 677,000 gallons.

The year 1890 being a census year, I have obtained from Captain Lusk, of the District water office, a plat of the city, including Georgetown, showing the actual areas, block by block, to which Potomac water was supplied by the distribution system of the District of Columbia.

On my sending this plat to the Hon. Mr. Porter, Superintendent of the Census of 1890, with great kindness he has had very carefully estimated the population within this area. It is 187,000. From this, and the average consumption and waste during the last fiscal year, I find the daily consumption and waste *per capita* in this area to have been 196 gallons. The measurements on December 29, 1890, and June 24, 1891, show that the daily consumption and waste *per capita* in the same area on these days was 207 gallons.

Taking the total population of Washington and Georgetown (202,978) at the time of the census of 1890, and dividing it into the total daily amount of water consumed and wasted in the last fiscal year, the average daily amount *per capita* would be 180 gallons.* This would not be correct, since, assuming the census estimate of the population within

*In the United States, the consumption and waste of water in cities not often exceeds 100 gallons *per capita*, and, as far as I know there is not more than one such case in Europe. This startling amount of 180 gallons *per capita* for the entire population of Washington and Georgetown may suggest to the District government an extension of the present limited application of the meter system, not generally, but in a moderate way, say to all breweries, factories, hotels, livery stables, and all similar cases where there are extensive wastes, and where the proprietors for *business purposes* use great amounts of water, making, it may in a sense be considered, a money profit from its use. Should this be done, I think it probable that the present rates to private consumers might be reduced without any reduction of the District's income from water, and it would certainly tend to postpone the need of raising the dam at Great Falls for the purpose of increasing the supply from the Potomac to the conduit, the early necessity of which I have mentioned elsewhere in this report.

the area supplied with Potomac water to be correct, there are outside this area 15,978 of the population that are supplied from wells, (or from sources other than the Potomac), but it is doubtless the usual and the only mode that is practicable to compilers of statistical information respecting the consumption and waste of water *per capita* in cities.

This rule would give for the average daily consumption and waste *per capita* in Washington and Georgetown in 1870 and 1880, 115 and 151 gallons respectively.*

NECESSITY FOR FURTHER APPROPRIATIONS.

The aqueduct and the works connected with it are generally in excellent condition, but it is my duty to call especial attention to several improvements that are urgently needed. Most of them were mentioned in my last annual report.

IMPROVING THE CONDITION OF THE POTOMAC WATER AND INCREASING THE CAPACITY FOR ITS STORAGE.

Now that the city is everywhere abundantly supplied with water, except at a few points where its proper distribution is interfered with by the small size and the reduction in capacity by internal corrosion of the city's street mains and the service pipes leading from them to residences, one of the most important works to be done in connection with the aqueduct is to furnish the city with better water; or, since the water of the Potomac as brought from Great Falls is, I am convinced, perfectly wholesome at all times, it would be more correct to say with clearer water.

The muddiness of the water supplied to the city arises from the earthy matter carried down to the Upper Potomac and its tributaries in storms and most abundantly in winter and early spring, by reason of the alternate freezing and thawing of the ground.

The following table gives the number of days in the 4 years ending June 30, 1889, on which the water had different degrees of turbidity at Great Falls:

Fiscal year.	Clear.	Slightly turbid.	Turbid.	Very turbid.
1885–'86	127	86	51	151
1886–'87	164	29	51	121
1887–'88	194	15	26	131
1888–'89	147	33	50	135
Average for 4 years	158	28	44	134

The following table gives the number of days in the 4 years ending June 30, 1889, on which the water had different degrees of turbidity at the effluent gate-house at the distributing reservoir, after passing through the reservoir to the mains leading to the city:

Fiscal year.	Clear.	Slightly turbid.	Turbid.	Very turbid.
1885–'86	147	35	72	111
1886–'87	256	30	32	38
1887–'88	240	16	52	58
1888–'89	193	24	64	84
Average for 4 years	209	28	55	73

* The population of Washington in 1870, 1880, and 1890, was 109,199, 147,293, and 188,932, respectively. The population of Georgetown in the same years was 11,384, 12,578, and 14,046, respectively. The population of the entire District of Columbia in 1890 was 230,392.

It will be observed that the total time that the water was "turbid" and "very turbid" at the distributing reservoir was only about two-thirds of the total time that it was "turbid" and "very turbid" at Great Falls, and this great improvement in the water supplied to the city, as compared with its condition when it entered the conduit, was due to the time, short as it was, given for depositing its earthy (clayey) matter in the distributing reservoir.

Filtering the water consumed by the cities of Washington and Georgetown would be enormously expensive (it has been estimated that the first cost of filtration works would be from $600,000 to $800,000, and the annual cost from $18,000 to $43,000, according to the plan adopted). We have now no "head" to spare for it, and we can get no head for it without pumping.

Except by pumping there can be no filtration without loss of head that we now have, and for every foot of head lost in our case, there would be a section of Capitol Hill and a section of the northern portion of the city that would be deprived of the water that is now supplied to them.

Even if it should be decided at some time in the future that resort must be had to filters, it will be necessary, in order to save a great part of their cost of maintenance, to "settle" the water as much as possible before it enters the filters.

Turbidity does not necessarily make waters unwholesome. The clearest waters are sometimes the most dangerous because they are deceptive, and filtration can, at most, only make waters clear.

During the times of its turbidity the Potomac water has caused resort to the clear but deceptive well waters of the city for drinking purposes, and they doubtless have caused disease which has been attributed to Potomac water; and some years ago, when the Potomac water was allowed to flow through the receiving reservoir and mingle with the water of this reservoir, it had a disagreeable, fishy, and oily taste and smell, and there was much complaint; but the Potomac water itself, brought either directly from Great Falls or through the distributing reservoir, has never, even in its worst condition, been proved to be unhealthful; on the contrary, it has been generally believed to be one of the best in the country.

Filtration, except by pumping the entire quantity of water consumed and wasted in Washington and Georgetown, being then out of the question, a comparison of the foregoing tables clearly points out the most important step to be taken for improving the condition of the Potomac water.

It is to provide an additional settling basin, so that when the river is turbid the water can have a longer time for depositing its sedimentary matter before passing into the mains.

This can be done by improving the receiving reservoir.

The receiving reservoir, about 2 miles, following the Conduit Road above the distributing reservoir, has about the same area as the latter, and contains about the same available amount of water.

Its perimeter has a length of about 2 miles. The conduit from Great Falls to the distributing reservoir passes close to a portion of the margin of the receiving reservoir, and there is an inlet from the conduit to the latter reservoir at its upper end, and an outlet from the reservoir to the conduit at its lower end. They are so arranged that the water in its route from Great Falls to the distributing reservoir can be made to pass either directly through the conduit and around the receiving reser-

voir to the distributing reservoir, or through the receiving reservoir, as may be desired.

It was contemplated in the original design for the aqueduct that the water from Great Falls should always pass through the receiving reservoir, and the latter was intended to serve mainly as a settling basin; but its use as such, and all use, was, for reasons to be stated, suspended some years ago.

Unlike the distributing reservoir, which has no watershed, the receiving reservoir has an extended watershed of about 4,000 acres. It is mainly to the northward of the reservoir, its northern border crossing the Tenallytown and Rockville road, about 2½ miles above Tenallytown. Its eastern border follows pretty closely the Loughborough and the Tenallytown and Rockville roads, and its general width from east to west is about 2 miles. The greater part of the area of the watershed is very hilly, and nearly the whole of it is devoted to cultivation and grazing.

The population upon it is quite large, and it is rapidly increasing. The water falling upon this area is carried to the reservoir by several streams, one of which, Little Falls Branch, is of considerable size, and they carry in storms and heavy showers great quantities of detritus, which is rapidly shoaling the reservoir. With the receiving reservoir in its present condition there is no means of excluding the drainage water from the surrounding lands, and if the Potomac water from Great Falls be permitted to flow through the reservoir, of preventing the mingling of these two waters, and so many complaints were made some years ago in the public press and by the water-takers that the passage of Potomac water through the reservoir was stopped and the reservoir was cut out from the system of supply to the city.

These complaints were doubtless well founded.

Every storm and heavy shower brings down to the reservoir through the streams that lead into it and directly from the hillsides, not only a great quantity of muddy water which roils the reservoir, but probably some of the fertilizers and other deleterious substances from the cultivated and grazing lands of its watershed. In fact, this reservoir has the usual defects of reservoirs surrounded by and supplied from cultivated and inhabited districts. A considerable portion of the margin of the reservoir is shoal, with soft, muddy bottom. The waves stir up the mud and add to the muddy water brought down by the streams, and in other portions of the shoal water, near the shore, there is a luxuriant growth of water plants of various kinds, and the water there being quiet and protected from the waves, there is promoted in these places growths of *Algæ* and other minute vegetable substances that have given so much trouble in the reservoirs of other cities, as well as in the receiving reservoir, and to which is attributed the offensive oily and fishy smell and taste of their waters at some seasons of the year, especially in hot weather.

This was the particular cause of complaint in Washington when this reservoir was thrown out of service.

The receiving reservoir is admirably suited for settling purposes, if all water be excluded from it except the water from the Potomac and the margins be deepened and protected.

These can readily be done if Congress will grant the necessary appropriations.

Captain Symons, of the Engineers, some years ago conceived an excellent, and I believe the only practicable, project for the former, and it,

and the drawings illustrating it, may be found in the Report of the Chief of Engineers for 1885, pages 2464–2468.

His project, which I have carefully examined and tested, is to take the waters of East Creek (the stream farthest to the eastward that pollutes the reservoir) and conduct it in an open and paved channel to Mill Creek, together with all the water falling directly into the reservoir from the hills between these two streams; then to take the combined waters of both streams and the water which falls directly into the reservoir from the hillsides between Mill Creek and Little Falls Branch by a proportionally larger channel and a short tunnel to Little Falls Branch. The combined waters of all the streams are then to be taken by a still larger channel and another short tunnel to a natural water-course below the reservoir.

To catch and throw all the water of the streams into these channels and connecting tunnels, small dams are to be erected across the mouths of the streams below the points where the artificial channels enter and leave their basins, which points are in all cases as close to the reservoir as possible.

The work is planned to give the shortest tunnel lines possible, and both the channels and the tunnels were computed to carry off the greatest known rainfall.

The plan would make this splendid reservoir, which has capacity for about 175,000,000 of gallons of water, which cost many thousands of dollars and is now useless, fully as valuable for settling purposes, and as completely shut off from all polluting influences, as the distributing reservoir. By it the receiving reservoir would become an additional distributing reservoir, and the time allowed for settling would be considerably more than double the time now allowed. It would give the water from Great Falls, after reaching the "north connection" of the receiving reservoir, a variety of routes for reaching the mains leading to the city, and either could be adopted as the varying conditions of the water might require, as follows: It could be made to pass through the receiving reservoir, thence through the conduit to the distributing reservoir, and through this reservoir, or it could be made to pass around the receiving reservoir and thence to and through the distributing reservoir, using either reservoir alternately as a settling basin, or, when the water at Great Falls is quite clear, as it is (see the foregoing table) about one-half of the time, it could be made to pass from Great Falls directly into the mains without passing through either reservoir.

The estimate of the cost of excluding the water of the surrounding country from the receiving reservoir, including the purchase of the small amount of land required and the cost of completing the fencing of the reservoir lands, was $130,000. From this I would deduct $15,346, the then estimated cost of deepening and protecting the margins of the reservoir, as far as was possible at the time (the water could not then be drawn from the reservoir without great and prolonged inconvenience to the people of Washington), and add $14,000 for a probable increase in the value of the land to be acquired, and 5 cents per cubic yard to the then estimated cost of earth excavation, or $1,130, making in round numbers $129,800.

To obviate the defects of the reservoir caused by shoal water, I would deepen the water everywhere at its margins to 12 feet, and protect the sides by slope walls of dry rubblestone 12 inches thick, laid upon a lining of broken stone 6 inches thick, precisely as the sides of the distributing reservoir are now protected, at the following estimated cost:

148,300 cubic yards of excavation, at 35 cents	$51,905.00
16,400 cubic yards of dry stone masonry, at $4.50	73,800.00
8,200 cubic yards of broken stone lining, at $2.50	20,500.00
	146,205.00
Add 10 per cent. for contingencies	14,620.50
	160,825.50

Adding to the latter amount $129,800, the estimated cost of cutting off all access of the water from the water-shed of this reservoir and the purchase of the land required, and we have for the thorough improvement and completion of the receiving reservoir $290,625.

The improvement of the receiving reservoir as just indicated is necessary not only for the purpose of reducing the turbidity of the water supplied to the city, but for restoring the storage capacity of our aqueduct system.

With the double object, then, of improving the quality of our Potomac water and of restoring our reservoir capacity for storage, I can not too earnestly urge that the estimate for an appropriation for the improvement of the receiving reservoir, which will be found included in my estimate for the next fiscal year, be granted by Congress.

LOWERING THE HEIGHT OF THE CROSS DAM IN THE DISTRIBUTING RESERVOIR.

The lower reservoir, the distributing reservoir, is divided about half way between the influent and the effluent gate-houses by a cross dam, in the middle of the length of which is a narrow cut lined with masonry, through which all the water on its way to the effluent gate-house, where it enters the mains, must pass.

The draft through this cut is so strong that the major part of the water is drawn straight from the influent gate-house, which is in a corner of the upper division, the settling division, to the cut, so that when the water coming down the cut is turbid it does not diffuse itself through the whole body of water in this division (110,000,000 gallons) as it should in order that the greatest amount of settling be done.

Neither is the water after it passes through the cut properly distributed through the lower division, which contains about 60,000,000 gallons, for the reason that the draft from the cut to the head of the mains leading to the city from the lower end of the division is so strong that the water all passes in a comparatively narrow stream straight to these mains, so that it also gets very little chance to settle in this division.

Now, as the upper layer of any body of water not quite free of turbidity and in the process of settling is the clearest, if the top of the dam be lowered far enough to allow only a thin sheet (at the present rate of consumption it would be less than an inch deep) of water to pass over the dam, as was General Meigs's design, we should have in each divition a very effective additional means of clarifying the aqueduct water, and I believe that this improvement in the distributing reservoir being made, and the receiving reservoir being improved as recommended, there would be but rarely, if any, complaint of muddy water.

I estimate the cost of this improvement at the distributing reservoir by lowering the cross dam at $12,500.

PROTECTION OF THE INLET TO THE CONDUIT AT GREAT FALLS.

The bank of the Chesapeake and Ohio Canal, which runs parallel to the Potomac at Great Falls, and about 150 feet from it, is about 16½ feet

higher than the uncovered chamber, just above the Maryland end of the aqueduct dam, that forms the inlet from the river to the conduit.

In the flood of November, 1877, which rose at Great Falls to the height of 160 feet above the datum of the aqueduct, or 12 feet higher than the crest of the dam, the canal bank at a point opposite the inlet was washed down to the river and a part of it into the inlet. I quote from the annual report of the aqueduct for 1878:

The masonry forming the arch of the feeder was uncovered from a point near the middle of the canal to the mouth of the feeder, a distance of 150 feet. The chamber at the head of the aqueduct was filled with stones that had formed the slope wall of the canal, and the aqueduct feeder, for a distance of 300 feet, was filled with débris to depths varying from 3 to 6 feet, so as to entirely stop the flow of water during the ordinary low stages of the river.

In the still higher flood of June, 1889, which rose to the height of 16 feet over the aqueduct dam, the canal bank was again washed down to the river, but fortunately the damage did not occur immediately opposite the inlet to the conduit, but from 200 to 400 feet higher up, so that the major part of the débris being left on the margin of the river, and a part of it being carried over the dam, not so much filling of the inlet to the conduit was done, but as in the flood of 1877 it was partially obstructed.

The annual report of the aqueduct for 1889 says:

The banks of the Chesapeake and Ohio Canal above and below the mouth of the conduit were carried away, and that opposite the conduit was threatened; a number of men were kept at work on this bank during the freshet, and it is believed that had it not been for the energetic work of this force, and the widening and strengthening of the bank at this locality in April, great damages would have occurred at the mouth of the conduit.

It will be observed that in the freshet of 1877 not only the inlet chamber but the conduit itself was filled to a depth of from 3 to 6 feet *for a distance of 300 feet in from its mouth*, but the water in the river being at a high stage there was still water way enough in the conduit above the débris to enable the supply to the city to be kept up. Had a complete closure of the mouth of the conduit occurred, with 12 to 16 feet of water over it, there would have been no possible way, with the torrent raging over the mouth, to remove the obstruction before the river subsided, and the water supply to the city would have been cut off.

There is no more important part of our system of water supply to be carefully guarded than the head of the conduit at Great Falls, and in order to avert dangers like those of 1877 and 1889, to which the water supply is liable in every freshet, a masonry wall should be built between the river and the canal bank, rising a few feet higher than the latter, and extending up river from the mouth of the conduit as far as the limit of the Government land, and thence at about a right angle and still on the Goverment land, to the shore of the river. I estimate the cost of this wall at $5,000.

EXTENSION OF OUTLET OF WASTEWEIR NO. 3.

In order to provide means for emptying the conduit in case of a break in it, or for any purpose of repair, and to regulate the quantity of water passing down the conduit, three wasteweirs or openings, from the conduit are provided in its 11½ miles of length. One of the most important of them is wasteweir No. 3, which is between the receiving reservoir and the distributing reservoirs, and about half a mile above the latter. One of its most important functions is to enable us to control the height

of water in the distributing reservoir, so that, on the one hand, it shall not fall below the height required to give the best possible supply to the city, and, on the other, it shall not rise so high as to endanger the dams of the reservoir. This is ordinarily done by telephonic orders to the watchman gatekeeper at Great Falls, who is in charge of the gates at the head of the conduit, but in case of a break in the telephone line, and communication with him, except by mail, being cut off, reliance must be had on the wasteweirs, and especially on No. 3, which is in charge of the watchman gatekeeper at the distributing reservoir. The overflow from this wasteweir is, for the distance of about 270 feet, in a deep gully through private property to a natural water course and thence under the Chesapeake and Ohio Canal to the Potomac. Property in this vicinity is getting to be valuable, streets are being laid out through it, and the outflow from the wasteweir is liable to be obstructed by the filling of the gully by the owners of the land. The difficulty can be obviated by laying a 36-inch cast-iron pipe in the gully from the wasteweir to the natural water course, at an estimated expense of $2,500.

DEEPENING THE DISTRIBUTING RESERVOIR.

The present bottom of the distributing reservoir being at reference 135 above the aqueduct datum, and the flow line of the reservoir being at reference 146 above this datum, the available depth of water is 11 feet.

It has often been recommended in former annual reports that the depth be increased 13 feet, or to reference 122, the depth of the axes of the four 48-inch connections between the screen house and the gate chamber.

This would increase the storage capacity of the reservoir from about 170,000,000 gallons to about 290,000,000 gallons, and add to the coolness of the water and also to its purity, for, unlike the receiving reservoir, which is nearly surrounded by woods, the distributing reservoir is fully exposed to winds, and the waves are sometimes so great as to disturb the bottom and make the water roily.

Should this be done, bermes of 10 feet in width should be left at the foot of the present slope walls protecting the sides of the reservoir the tops of these bermes should be paved, and the deepened portions of the sides should be protected by slope-walls of dry rubble masonry 12 inches thick, laid on a broken-stone lining 6 inches thick.

I estimate the cost of the work at $290,000 in round numbers, as follows:

580,000 cubic yards of excavation, at 35 cents	$203,000
10,500 cubic yards of rubble slope wall, at $4.50	47,250
5,300 cubic yards of broken-stone lining, at $2.50	13,250
	263,500
Add 10 per cent. for contingencies	26,350
	289,850

I consider the work of deepening this reservoir to be of very great importance for the reasons given, and it should be done as soon as appropriations can be obtained for it, but as the improvement of the quality of the aqueduct water, the increase of storage capacity above the heads of our mains, the protection of the aqueduct, and other works herein mentioned are of more importance at this time, I have not included it in the estimates for the next fiscal year.

STORAGE YARDS.

I have provided supplies for use in case of breaks in the 48-inch and other mains, comprising sections of pipe, curves, crosses, reducers, sleeves, etc., a heavy wagon for hauling them where needed, lifting jacks, and efficient pumps; also machinery for lowering the pipes in the trenches and the implements and material required for handling and calking.

A portion of these supplies has been placed in a yard which I have arranged on the public land at the distributing reservoir, for use in the country portions of the routes of the mains, and the remainder for use in the city portions of these routes has been placed in a portion of Twenty-seventh street, near M Street Bridge, which has been loaned for the purpose by the District government until the street is wanted for improvement.

As we shall not be able probably to retain this place except for a short time, a permanent yard in the city should be purchased for use as a storage yard. It should be near this office, and at or near the grade of the street, so that the heavy castings and machinery required for repairs can be quickly gotten out.

I believe that a suitable lot can be obtained by purchase, or, if need be, by condemnation, for $10,000, and I recommend an appropriation of this amount for the purpose.

CLEANING THE BOTTOM OF THE DISTRIBUTING RESERVIOR.

The sedimentary deposits of about twenty years, within which time the distributing reservoir has not been cleaned out, have raised the bottom of its upper division, the settling division, about 9 inches, and of the lower division about 4 inches.

These deposits have diminished the capacity of the reservoir about 8,000,000 gallons, and although it is probable that these deposits, which are mostly clay, are not deleterious to the water, they should be removed as soon as an appropriation can be obtained for the purpose. It would require the removal of about 39,500 cubic yards, the estimated cost of which, at 35 cents per cubic yard, is $13,825.

RAISING THE HEIGHT OF THE DAM AT GREAT FALLS.

I have already stated in this report the fact that I find that the height of the dam at Great Falls is not sufficient at low stages of the river to keep the conduit full at its head, or to enable it to deliver as much water as is now consumed and wasted in the city and at the same time keep up the head in the mains at the distributing reservoir to 146 feet above datum, which is necessary for the supply by gravity of the high northern portions of the city and of Capitol Hill, and that the only remedy for this, and it is one that should be made before any further steps are taken for increasing the supply from the distributing reservoir to the city, is the raising of the dam. The following is an estimate of the cost of the work:

2,134 cubic yards of stone masonry, at $35	$74, 690
3,333 cubic yards of riprap, at $2	6, 666
Damages on account of flooding of land, and other damages	12, 000
	93, 356
Add 10 per cent. for contingencies	9, 335
	102, 691

This is a work that will soon have to be done, but as it can not be done before the Chesapeake and Ohio Canal is repaired and again put in operation so that we can get the required stone from the Government quarry at Seneca, I do not include an estimate for it in the estimates for the next fiscal year.

DESIRED PROVISION IN RESPECT OF APPROPRIATIONS FOR THE AQUEDUCT.

Appropriations for the aqueduct are now fiscal year appropriations, and their availability terminates on the 30th of June of each year. Whenever appropriations are delayed there is liable to be a time in the early part of every other fiscal year during which, should a break occur in a main either in the city or in the country this side of the distributing reservoir or in the conduit, or should any disaster occur at the reservoir or at Great Falls, there is no money available for repairs.

An example of the urgent need of a change in this respect is the recent repair of the dam which retains the water for supplying the conduit at Great Falls. It was a most important work and one that could be done only at the lowest stages of the river. Every rain stopped it and caused a loss of time and money. For a few weeks preceding the close of the fiscal year there had been an exceptionally favorable time for the work, and it was pushed forward with all the rapidity possible, up to the evening of the 30th of June, when, by reason of the limit of the appropriation as to time, it was necessary to discharge the workmen and wait for a new appropriation which, even if it should be made early in July, would not be available at the Treasury until some weeks later.

If the appropriations for the aqueduct should be made available until expended, some of the less urgent repairs towards the end of the year could be postponed until the next appropriation should become available, so that there would always be money in hand for repairing a break in a main, or for any other work like the one mentioned at Great Falls, that can not be postponed without loss.

A leak in one of the city's old and decayed street mains, or in one of the hundreds of small service pipes that cross the route of the 48-inch main, for instance, by undermining it may cause it to break, and the quantity of water that would be discharged on the street, especially in the low levels of the route, would be so enormous that property and even life itself might be endangered.

And in case of appropriations for specific works like those I have recommended it is sometimes not advantageous, either in respect of economy or the quality of the work, to oblige the work to be fully completed at the end of the fiscal year.

Sometimes, by reason of the late date at which appropriations become available, or of the weather, or of the condition of the river, the work can not be fully completed within this time without hurrying it so much as to be detrimental to the interests of the Government. I do not know of any appropriations that more require to be made available until expended, like appropriations for river and harbor improvements, than appropriations for the Washington Aqueduct. I urgently recommend, therefore, that it be done, and also that the same facilities that were provided in the act of March 2, 1889, making an appropriation for the construction of the 48-inch main, be provided for every part of the work pertaining to the aqueduct, and beg to suggest that the following clause

be attached to the next appropriations for the aqueduct and be made to operate on all future appropriations for it:

Provided, That all appropriations for the Washington Aqueduct shall be available until expended, and if it shall appear to the Secretary of War, on the report of the Chief of Engineers, that for any cause any work pertaining to said aqueduct can not be carried on or material therefor can not be obtained as rapidly as is necessary for the best and most vigorous prosecution of it, he is authorized to provide material by purchase in open market or by contract for the fabrication thereof, and to carry on the work by day's labor or otherwise, as may seem to him expedient.

The height of the water above the dam at the inlet to the aqueduct at Great Falls varied during the year from a minimum of 0.6 foot on July 31–August 6, 1890, to a maximum of 5.7 feet on April 2, 1891.

Mr. R. C. Smead has performed his duties in connection with the 48-inch main and of superintending the working of the aqueduct and its adjuncts satisfactorily during the year. Mr. Thomas Sullivan, Mr. John Halloran, and Mr. Daniel Harrington, for many years watchmen gate-keepers at Great Falls and at the receiving and distributing reservoirs, have attended to their important duties faithfully. In addition to their other duties they have skillfully and energetically acted as foremen of laborers engaged on the works of repair.

A map of the route of the Washington Aqueduct accompanies this report.

The following is a money statement for the fiscal year ending June 30, 1891:

July 1, 1890, balance unexpended		$3,083.26
Amount appropriated by act approved August 6, 1890		25,500.00
Amount appropriated by act approved March 3, 1891		20,000.00
		48,583.26
June 30, 1891, amount expended during fiscal year		19,139.01
July 1, 1891, balance unexpended		29,444.25
July 1, 1891, outstanding liabilities	$1,434.25	
July 1, 1891, amount covered by uncompleted contract	2,510.00	
Amount of appropriation of August 6, 1890, to be reverted to the Treasury	5,500.00	
		9,444.25
July 1, 1891, balance available		20,000.00

The estimates of appropriations that should be made for the year ending June 30, 1893, are as follows, and I urgently recommend that the provisions of law suggested in this report be attached to the next appropriations for the reasons stated:

For improving the quality of the Potomac water and restoring the capacity for its storage by improving the receiving reservoir, including the purchase or condemnation of the necessary land	$290,625
For further improving the quality of the Potomac water by lowering the height of the cross dam at the distributing reservoir	12,500
For protecting the inlet to the aqueduct at Great Falls	5,000
For extending the outlet of waste weir No. 3	2,500
For purchase or condemnation of a site for a storage yard	10,000
For cleaning out the distributing reservoir	13,825
For maintenance and repairs of the aqueduct and the reservoirs, mains, roads, etc., connected therewith	21,000
	355,450

An increase of $1,000 over the appropriation of former years for maintenance and repairs is made necessary by the increased amount that will be required by the addition of the 48-inch and the other new mains to the former system of supply.

Hourly and total flow from distributing reservoir for the twenty-four hours ending at noon June 25, 1891. City temperature in the shade at 2 p. m. June 24, 79°.

Date.	Outflow per hour.	Date.	Outflow per hour.
June 24—	*Gallons.*	June 25—	*Gallons.*
From 12 noon to 1 p. m	1,559,396	From 12 midnight to 1 a. m	1,253,551
From 1 p. m. to 2 p. m	1,689,742	From 1 a. m. to 2 a. m	1,391,678
From 2 p. m. to 3 p. m	1,968,901	From 2 a. m. to 3 a. m	1,390,466
From 3 p. m. to 4 p. m	1,960,720	From 3 a. m. to 4 a. m	1,250,399
From 4 p. m. to 5 p. m	1,403,312	From 4 a. m. to 5 a. m	1,388,163
From 5 p. m. to 6 p. m	1,542,285	From 5 a. m. to 6 a. m	1,386,950
From 6 p. m. to 7 p. m	1,400,767	From 6 a. m. to 7 a. m	1,662,717
From 7 p. m. to 8 p. m	1,679,320	From 7 a. m. to 8 a. m	2,076,123
From 8 p. m. to 9 p. m	1,398,100	From 8 a. m. to 9 a. m	1,796,843
From 9 p. m. to 10 p. m	1,536,468	From 9 a. m. to 10 a. m	1,794,903
From 10 p. m. to 11 p. m	1,813,930	From 10 a. m. to 11 a. m	2,068,609
From 11 p. m. to 12 m	1,893,980	From 11 a. m. to 12 noon	1,790,420
		Total	38,594,743

Monthly measurements of the consumption and waste of water in the last fiscal year.

Date.	Gallons.	Date.	Gallons.
Wednesday, August 27, 1890	35,033,069	Wednesday, January 28, 1891	36,589,949
Monday, September 8, 1890	35,679,672	Thursday, February 26, 1891	37,005,091
Saturday, September 27, 1890	36,470,882	Wednesday, March 25, 1891	36,845,901
Tuesday, October 28, 1890	34,764,656	Wednesday, April 29, 1891	37,614,544
Tuesday, November 25, 1890	35,989,643	Wednesday, May 27, 1891	35,674,115
Monday, December 29, 1890	38,800,680	Wednesday, June 24, 1891	38,594,743

Consumption and waste of water as measured annually in the latter part of June of each year from 1874 to 1891, both inclusive.

Year.	Gallons.	Year.	Gallons.	Year.	Gallons.
1874	17,554,848	1880	25,740,138	1886	25,542,476
1875	21,000,000	1881	26,525,991	1887	26,878,424
1876	24,177,797	1882	29,727,864	1888	29,115,774
1877	23,252,932	1883	24,314,715	1889	27,708,779
1878	24,885,945	1884	24,827,113	1890*	35,541,845
1879	25,947,642	1885	25,219,194	1891	38,594,743

*Forty-eight inch main added to the supply.

Condition of water at Great Falls receiving reservoir and distributing reservoir and height of water over dam at Great Falls for each day in the year.

Day of month.	July, 1890. Condition of water. Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gate house.	Height of water over dam at Great Falls, feet.	August, 1890. Condition of water. Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gate house.	Height of water over dam at Great Falls, feet.	September, 1890. Condition of water. Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gate house.	Height of water over dam at Great Falls, feet.	October, 1890. Condition of water. Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gate house.	Height of water over dam at Great Falls, feet.
1	22	36	15	1.30	36	36	36	.60	15	36	8	1.00	36	36	36	1.00
2	9	36	17	1.20	26	36	36	.60	6	36	12	1.00	36	36	36	1.00
3	3	36	21	1.60	36	36	36	.60	8	36	19	1.00	10	36	36	1.20
4	1	36	23	1.40	12	36	36	.60	14	36	22	1.00	2	36	36	1.10
5	1	36	8	1.30	22	36	36	.60	21	36	23	.90	2	36	17	1.10
6	2	36	3	1.30	36	36	36	.60	11	36	27	1.20	2	36	9	1.10
7	3	36	3	1.30	36	36	36	.70	3	36	28	1.00	2	36	8	1.20
8	10	36	4	1.20	6	36	36	.70	3	36	24	1.00	4	36	7	1.30
9	24	36	6	1.10	3	36	36	.80	5	36	24	.90	5	36	7	1.20
10	28	36	9	1.00	3	36	36	1.50	20	36	19	.80	7	36	12	1.20
11	32	36	9	1.00	2	36	24	1.10	19	36	23	1.00	7	36	15	1.20
12	36	36	17	.90	7	36	15	1.00	5	36	31	1.10	10	36	17	1.20
13	36	36	22	.90	12	36	11	1.00	3	19	32	1.30	12	30	21	1.20
14	36	36	36	.80	6	36	10	.80	2	20	20	1.60	14	36	33	1.10
15	36	36	36	.70	2	36	12	.90	2	25	12	1.60	18	36	36	1.10
16	36	36	36	.70	4	36	15	.80	4	30	9	1.40	4	36	30	1.20
17	36	36	36	.70	6	36	9	.70	2	36	6	1.30	6	36	26	1.50
18	36	36	36	.70	12	34	10	.70	2	36	6	1.20	6	36	24	1.40
19	36	36	36	.70	23	36	12	.70	5	36	6	1.10	8	36	22	1.40
20	36	36	36	.70	25	36	16	.80	5	36	7	1.10	8	36	23	1.30
21	2	36	36	.70	8	36	22	1.20	8	36	7	1.10	10	36	27	1.30
22	31	36	36	.70	2	36	28	1.40	8	36	9	1.10	12	36	28	1.20
23	36	36	36	.70	1	36	20	1.60	12	36	11	1.10	15	36	22	1.30
24	36	36	36	.70	1	36	7	1.30	17	36	13	1.00	4	24	23	2.50
25	36	36	36	.70	1	30	5	1.00	19	36	15	1.00	1	10	20	3.60
26	36	36	36	.70	2	36	4	1.20	20	36	15	1.00	1	10	10	2.80
27	36	36	36	.70	2	36	5	1.20	23	36	17	1.00	1	11	9	2.30
28	36	36	36	.70	2	36	5	1.00	26	36	20	1.00	4	9	4	1.90
29	36	36	36	.70	3	36	5	1.00	32	36	23	1.00	8	12	4	1.70
30	36	36	36	.70	10	36	5	1.00	34	36	28	1.00	10	16	6	1.60
31	36	36	36	.60	12	36	5	1.00	.....	.....	.....	.....	15	13	8	1.50

Day of month.	November. Great Falls.	Receiving reservoir.	Distributing reservoir.	Height, feet.	December. Great Falls.	Receiving reservoir.	Distributing reservoir.	Height, feet.	January. Great Falls.	Receiving reservoir.	Distributing reservoir.	Height, feet.	February. Great Falls.	Receiving reservoir.	Distributing reservoir.	Height, feet.
1..	20	14	11	1.40	36	36	36	1.00	31	36	26	1.10	3	10	9	3.60
2..	29	15	18	1.40	36	36	36	1.00	31	36	36	1.20	3	12	8	3.30
3..	30	20	23	1.40	36	36	36	1.00	6	36	36	1.60	2	12	10	3.90
4..	30	20	32	1.30	36	36	36	1.00	7	36	36	1.80	2	13	9	3.70
5..	36	23	36	1.30	36	36	36	1.00	4	36	20	2.50	3	17	11	3.00
6..	36	23	36	1.30	36	36	36	1.00	7	36	14	2.00	7	20	14	2.60
7..	36	30	36	1.20	36	36	36	1.00	7	36	12	1.60	10	15	12	2.30
8..	36	31	36	1.20	36	36	36	1.00	7	36	10	1.40	6	24	11	2.40
9..	36	36	36	1.10	36	36	36	1.00	8	36	10	1.40	3	15	10	2.10
10..	36	36	36	1.00	36	36	36	1.00	16	36	10	1.40	3	14	9	3.10
11..	36	36	36	1.00	36	36	36	1.00	20	36	11	1.30	5	12	4	3.30
12..	36	36	36	1.00	36	36	36	1.00	4	32	12	1.80	5	10	5	3.20
13..	36	36	36	1.00	36	36	36	.90	2	36	11	2.00	8	10	6	2.70
14..	36	36	36	1.00	36	36	36	.90	2	36	6	2.50	8	10	6	2.40
15..	36	36	36	1.00	36	36	36	.90	3	36	5	2.30	10	8	7	2.20
16..	36	36	36	1.30	36	36	36	.90	5	36	5	1.90	10	10	8	2.20
17..	36	36	36	1.30	36	36	36	.90	6	36	6	1.80	6	8	9	2.10
18..	36	36	36	1.30	12	36	36	1.40	12	36	6	1.60	5	8	11	2.80
19..	36	36	36	1.20	6	36	26	1.30	12	36	10	1.60	5	10	9	2.50
20..	36	36	36	1.20	6	36	36	1.30	12	36	8	1.60	6	11	8	2.30
21..	36	36	36	1.10	12	36	23	1.20	19	36	15	1.50	2	9	7	2.10
22..	36	36	36	1.10	20	36	22	1.20	16	32	11	1.50	5	7	9	2.30
23..	36	36	36	1.10	21	36	26	1.10	4	27	21	1.80	5	9	8	2.20
24..	36	36	36	1.10	26	36	30	1.10	2	14	13	2.50	8	8	9	2.40
25..	36	36	36	1.10	12	36	30	1.50	2	6	6	2.60	8	5	9	2.20
26..	36	36	36	1.10	8	36	36	1.50	4	7	4	2.40	8	6	10	2.00
27..	36	36	36	1.10	8	36	36	1.30	4	6	5	2.40	8	7	11	2.00
28..	36	36	36	1.00	15	36	36	1.20	7	7	7	2.00	17	7	13	1.80
29..	36	36	36	1.00	17	36	27	1.20	7	8	7	2.10	.....	.....	.....	.....
30..	36	36	36	1.00	22	36	25	1.20	9	11	9	2.50	.....	.....	.....	.....
31..	.....	.....	.....	.....	24	36	25	1.20	4	9	10	3.20	.....	.....	.....	.....

Condition of water at Great Falls receiving reservoir, etc.—Continued.

Day of month.	Condition of water.			Height of water over dam at Great Falls, feet.	Condition of water.			Height of water over dam at Great Falls, feet.	Condition of water.			Height of water over dam at Great Falls, feet.	Condition of water.			Height of water over dam at Great Falls, feet.
	Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gatehouse.		Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gatehouse.		Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gatehouse.		Great Falls.	Receiving reservoir, south connection.	Distributing reservoir, effluent gatehouse.	
	March.				April.				May.				June.			
1	17	6	14	1.70	2	7	15	4.00	36	34	36	1.10	5	36	36	1.60
2	27	6	16	1.70	1	10	10	5.70	36	31	36	1.10	26	36	36	1.50
3	29	8	19	1.60	1	6	5	5.20	36	32	36	1.10	36	36	30	1.40
4	36	8	23	1.60	2	5	3	4.10	36	36	36	1.10	33	36	36	1.30
5	30	8	30	1.50	3	6	3	3.80	30	36	36	1.10	4	36	36	1.30
6	36	9	36	1.50	5	4	4	3.20	36	36	36	1.10	9	36	36	1.20
7	36	10	36	1.50	8	5	4	2.70	36	36	36	1.00	16	36	36	1.10
8	30	10	36	1.50	17	4	6	2.40	36	36	36	1.00	9	36	36	1.20
9	9	11	36	1.70	22	6	7	2.20	36	36	36	1.00	6	36	36	1.30
10	2	12	36	2.60	20	8	12	2.00	36	36	36	1.00	7	36	36	1.70
11	2	12	30	2.80	28	8	14	1.90	36	36	36	1.00	8	36	36	1.60
12	2	12	16	2.80	1	5	17	2.70	36	36	36	1.00	12	36	36	1.40
13	1	10	12	3.00	2	6	11	3.80	36	36	36	1.00	19	36	36	1.30
14	2	4	4	3.60	4	5	6	2.90	36	36	36	1.00	25	36	36	1.20
15	2	4	5	3.30	8	5	6	2.40	36	36	36	90	28	36	36	1.30
16	3	4	6	2.60	18	6	6	2.20	36	36	36	.90	30	36	36	1.20
17	7	5	6	2.30	21	6	6	2.00	36	36	36	.90	34	36	36	1.10
18	15	5	7	2.10	27	8	11	1.90	36	36	36	.90	8	36	36	1.10
19	20	6	8	1.90	14	8	10	1.80	36	36	36	.90	2	36	36	1.20
20	17	6	9	1.80	25	10	15	1.70	36	36	36	.90	1	36	24	1.20
21	22	10	11	1.80	10	12	23	1.60	36	36	36	.90	2	36	11	1.50
22	8	12	15	1.90	14	13	20	1.50	36	36	36	.90	1	36	6	3.00
23	2	5	22	2.50	27	18	13	1.50	36	36	36	.90	1	30	5	2.30
24	2	6	14	3.00	23	25	19	1.60	36	36	36	.90	1	16	4	2.20
25	3	5	7	2.90	28	27	21	1.50	36	36	36	.90	2	18	3	1.80
26	6	5	5	2.50	23	25	24	1.40	36	36	36	.90	2	20	3	1.50
27	6	5	5	2.30	30	27	28	1.40	36	36	36	1.00	5	24	4	1.30
28	6	6	7	2.30	36	32	36	1.30	36	36	36	1.00	6	27	4	1.10
29	8	5	10	2.20	36	28	36	1.30	10	36	36	1.00	10	33	5	1.00
30	8	10	12	2.30	36	30	36	1.20	27	36	36	1.00	8	36	7	1.00
31	6	6	13	2.50					14	36	36	1.70				

Number of days during the fiscal year 1890–'91 on which the water was clear or turbid at the places indicated.

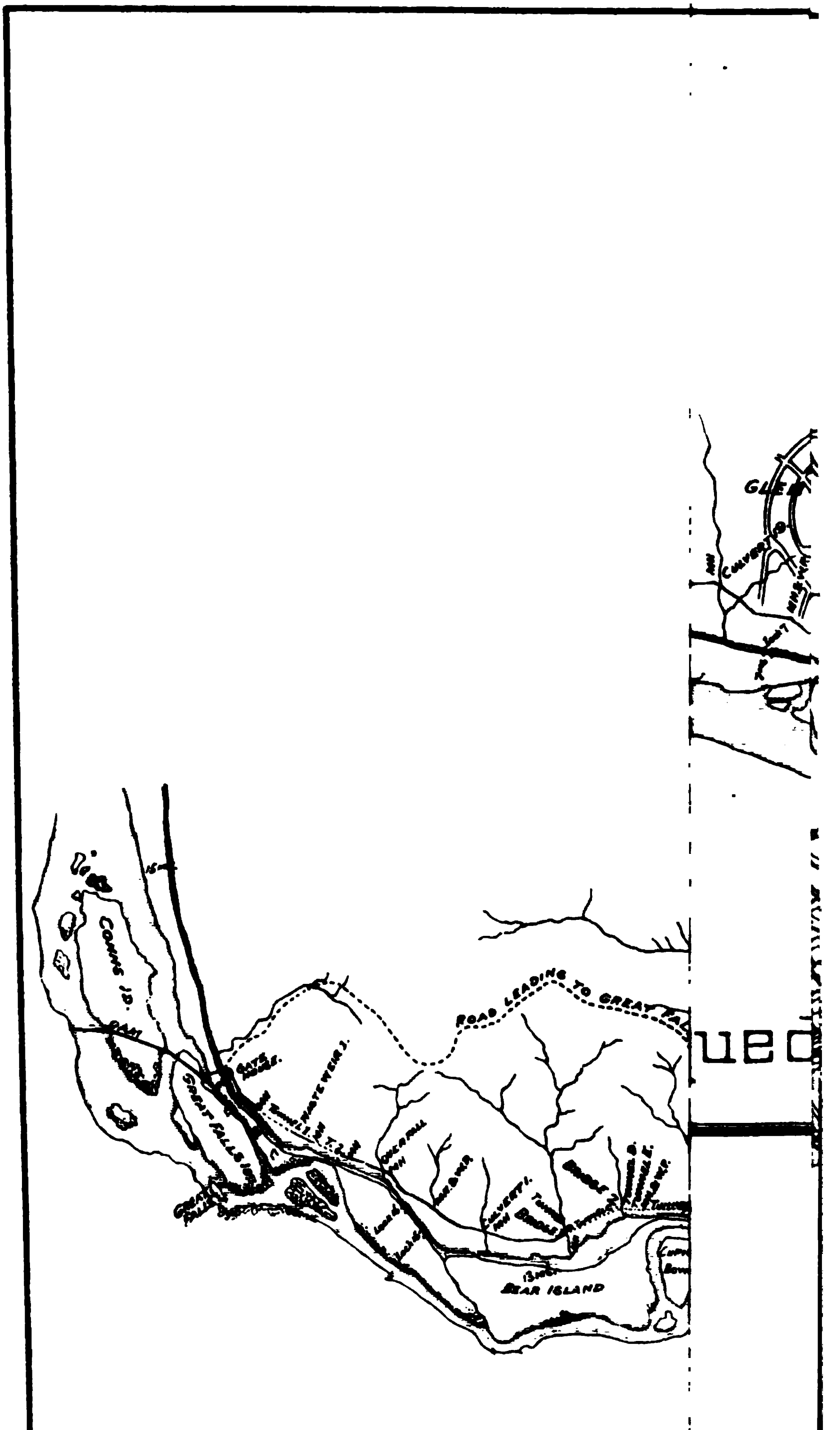
Place.	Clear.	Slightly turbid.	Turbid.	Very turbid.
Great Falls	144	30	61	130
Receiving reservoir	260	18	51	36
Distributing reservoir	188	35	84	58

NOTE.—In determining the condition of the water a metallic tube with glass ends is used. This is filled with water, and the distance at which a ball immersed in the water can be seen from one of the ends is noted. When it can be seen at a distance of from 22 to 36 inches inclusive it is considered clear; from 15 to 21 inches, slightly turbid; from 8 to 14 inches, turbid; and from 0 to 7 inches, very turbid.

Daily gauge pressures at the office of the Washington Aqueduct at 9 o'clock a. m.

Month.	Main.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Average.
1890.	Inch.																																
	30	36	36	36	36	36	38	35	35	35.5	35	35	35	36	35	35	35	35	35	35	35	35	34	34.5	35	35.5	35	36	35.5	35.5	35.5	35.5	35.37
July	36	35	35.5	35.5	36	36	39	38	36	36	36	36	36	38	36	38	38	38	38	38	38	40	36	38	38	38	38	38	38	39	39	39	37.35
	48	39	39	39	39	39	40	39	39	39	39	39	39	39	39	39	39	39	39	40	39	39	38	38	39	39	39	39.5	39	39.5	39.5	40	39.08
	30	35.5	36	36	35.5	35.5	35.5	35	35	36	36	35	35	36	35	35	35.5	36	36.5	36	36	35.5	35.5	35	36	35	35.5	35	34	34.5	34	36	35.41
August	36	38	40	40	40	40	40	40	38	39	39	39	40	39	40	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	39.70
	48	39	40	40	40	40	40	40	40	40	40	40	40	40	39.5	40	40	40	40	40	40	40	40	40	40	40	40	40	38	39	39	40	39.82
	30	35	35	35	35	35	35	35	35	34	35	34	35	35	36	36	35	34	35	35	35	36	35	35	35	35	34	35	35	34.5	34.5	....	34.93
September	36	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	....	40.00
	48	40	40	40	40	39.5	40	40	39.5	39	39	40	40	39.5	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	39.5	....	39.86
	30	34	35	35	36	37	35	35	35	35	35	35	35	35	35	35	35	36	37	37	37	37	37	37	37	37	37	37	37	35	35	36	35.83
October	36	40	40	40	38	39	38	38	38	38	39	36	39	37	37	38	38	40	40	38	40	40	40	40	40	39	40	40	40	40	40	40	39.03
	48	40	40	40	39	40	39	39.5	39	39	40	39	40	39	39	39	39	39	38	39	39	39	39	39	39	39	39	39	39	38	37	37	39.01
	30	37	37	37	37	37	37	37	37.5	38	37	37.5	37	37	38	37	38	38	37	37	37	37.5	37	37	37	36	36	36	36	37	37	....	37.05
November	36	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	39	39	39	40	40	40	40	40	40	40	40	40	....	39.90
	48	38	38	38	39	39	39	39	38	39	39	39	39	39	39	39	40	39.5	39	39	39	39	39	39	39	39	39	39	39	39	39	....	38.90
	30	36	37	37	36	36	37	37	37	35	36	36	37	36	37	37	37	37	37	37	36.5	37	36	37	37	37	37	37	37	36	35	36	36.53
December	36	40	40	40	39	40	40	40	40	40	35	37	37	37	37	37	37	37	40	37	37	39	37	37	37	37	37	37	36	36	35	36	37.77
	48	39	39	39	39	39	39	39	39	39	39	40	39	39	40	40	39	40	39	39.5	40	40	40	39	39	39	39	39	39	38	37	39	39.14
1891.																																	
	30	37	37	37	37	36	36	37	36	36	37	37	36	36	37	37	37	37	38	36	36	37	37	37	37	37	36	37	36	36	36	37	36.64
January	36	36	37	37	37	37	37	37	36	37	37	37	36	37	37	37	37	37	39	38	37	38	38	38	37	37	36	37	37	36	36	37	37.00
	48	38	39	39	39	40	38	39	39	39	39	40	38	39	39	39	39	39	40	39	39	39	39	39	39	40	39	39	39	39	38	39	39.00
	30	38	37	37	37	37	36	37	37	37	37	37	37	37	37	37	37	37	37	37	37.5	37	38	37	37	37	37	36	36	....	....	....	36.96
February	36	38	38	37	37	37	36	37	37	37	37	37	36	37	38	38	37	37	37	36	36	36	36	36	36	36	37	36	36	....	....	....	36.75
	48	39	40	39	40	39	39	40	39	40	40	39	39	39	39	39	39	39	39	39	40	40	40	40	40	39	39	38	39	....	....	....	39.32
	30	37	36	37	37	37	37	37	37	37	36	37	37	39	37	37	36	37	37	37	36	37	37	37	37	37	36	37	36	38	36	36	36.83
March	36	38	36	37	35	36	36	37	37	36	36	35	35	35	35	38	34	34	36	34	36	37	37	36	36	36	34	36	34	36	34	36	35.74
	48	39	40	39	39	39	39	40	40	40	39	40	40	39	40	40	39	40	40	40	40	40	40	40	40	40	39	40	40	40	40	40	39.70
	30	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	37	36	36	36	36	36	36	36	36	36	36	35	....	36.00
April	36	36	36	36	36	35	36	36	36	36	36	36	36	36	36	36	36	36	36	37	36	36	36	36	36	36	38	36	36	36	35	....	36.03
	48	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	39	39	40	40	40	40	40	40	39	38	....	39.83
	30	35	35	36	36	36	36	36	36	36	38	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	34	34	36	36	35.87
May	36	35	35	36	36	36	36	36	36	36	38	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	34	34	34	34	36	35.74
	48	38	39	40	40	39	40	40	40	40	40	39	40	40	40	40	40	40	40	40	(*)	39	40	39	40	39	39	39	38	38	38	39	39.43
	30	36	36	36	36	36	36	36	38	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	34	34	34	34	34	34	....	35.66
June	36	36	36	36	34	36	36	36	36	36	36	36	34	36	36	36	36	36	36	34	36	36	36	36	36	34	34	34	34	34	34	....	35.40
	48	39	39	39	39	39	39	40	39	39	39	38	38	38	40	40	39	39	38	39	39	39	39	39	38	36	37	37	38	37	37	....	38.53

* Cut off gauge pipes to lower it below cable road.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GATE HOUSE
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BEAR ISLAND
CULVERT

Appropriations made for the Washington Aqueduct, with the dates of acts for the same.

Date.	Amount.	Date.	Amount.	Date.	Amount.
Sept. 30, 1850	$500	Mar. 3, 1869	$25,000	Mar. 3, 1881	$20,000
Aug. 31, 1852 (a)	5,000	July 15, 1870 (b)	120,822	July 1, 1882 (g)	20,000
Mar. 3, 1853	100,000	Mar. 3, 1871	114,196	Mar. 3, 1883	20,000
Mar. 3, 1855	250,000	June 10, 1872	70,555	July 5, 1884	20,000
Aug. 18, 1856	250,000	Jan. 23, 1873	14,000	Feb. 25, 1885	20,000
Mar. 3, 1857	1,000,000	Mar. 3, 1873 (c)	43,600	July 9, 1886	20,000
June 12, 1858	800,000	June 23, 1874 (d)	36,400	Mar. 3, 1887	20,000
June 25, 1860	500,000	Mar. 3, 1875	26,000	July 18, 1888 (h)	20,000
July 4, 1864	150,000	July 31, 1876	22,000	Mar. 2, 1889	20,000
July 28, 1866	142,584	Mar. 3, 1877	15,000	Aug. 6, 1890 (i)	25,500
Dec. 20, 1866	12,000	June 20, 1878	15,000	Mar. 3, 1891	20,000
Mar. 2, 1867	20,000	Mar. 3, 1879 (e)	20,000		
July 25, 1868	52,500	June 4, 1880 (f)	20,000		4,050,657

NOTE.—Reverted to the Treasury: (a) $2.81, (b) $46.25, (c) $560.87, (d) 35 cents, (e) $1,109.87, (f) $381.06, (g) $1,354.17, (h) $2,266.34, (i) $5,500; total, $11,221.72. This sum being deducted from the total amount appropriated (not including the last appropriation) shows the amount ($4,019,435.28) expended to June 30, 1891. Since 1878 one-half the amounts appropriated have been contributed by the United States and the other half by the District of Columbia.

Abstract of proposals for five pillar cranes for the Washington Aqueduct, received in response to circular letter dated May 20, 1891, and opened June 4, 1891, by Lieut. Col. Geo. H. Elliot, Corps of Engineers.

1. The Yale and Towne Manufacturing Company of Stamford, Conn.:

One crane with an effective radius of 13 feet	$510.00
One crane with an effective radius of 9 feet	495.00
One crane with an effective radius of 12 feet	500.00
One crane with an effective radius of 10 feet	493.00
One crane with an effective radius of 15 feet	512.00
Total amount of bid	2,510.00

Only bid; contract made.

D D D 2.

WATER SUPPLY, DISTRICT OF COLUMBIA.

THE 48-INCH MAIN.

The work of laying the 48-inch main, for which $575,000 was appropriated by the act of March 2, 1889, and the laying of the 30-inch main on Capitol Hill, which was done by means of the same appropriation, were completed in the fiscal year 1889–'90. With the amount that remained of the appropriation, and as a remedy for the loss of head in the high area in the vicinity of M, N, and O streets NW., between Tenth and Thirteenth streets, arising from the small sizes and bad condition of the District's street mains, it was decided to lay a 24-inch main in Eleventh street NW., between K and U streets, and, for a similar reason, and looking to the future of Capitol Hill, it was decided to lay a new 30-inch main in New Jersey avenue, between B and L streets.

Contracts were made early in the last fiscal year for the materials for both of these mains, and on the 3d of October, 1890, sufficient of the pipe and special castings had been received to warrant the commencement of laying the Eleventh street main, which was steadily carried on until its completion, on the 14th of November. It is 5,142 feet or about 1 mile long. It connects at K street with the 30-inch main, at Massachusetts avenue with the 36-inch main, at R street with the 48-inch main, and at U street with a 12-inch District main. Connections were made

with the District's distributing mains at all the streets crossed by the 24-inch main from L to T streets, both inclusive. Like the 48-inch main, it is well provided with air valves at the summits, viz, at U and N streets, and on both sides of the 36-inch main at Massachusetts avenue. A 10-inch blow-off was placed at the only valley on the line, viz, at Q street, and small air taps were placed at M street and in the top of the 36-inch by 24-inch cross at Massachusetts avenue. Five 24-inch valves were placed in the main, viz, one at U street, one on each side of the 48-inch main at R street, and one on each side of the 36-inch main at Massachusetts avenue. The supply to the main is from the 48-inch main at R street. The main valve at Massachusetts avenue, north of the 36-inch main, is to be kept closed except in case of fire or other unusual draft on the 24-inch main. The gain in pressures in the vicinity of the main was very marked, as will be observed in the table appended to this report showing the pressures in pounds and the head in feet on Tenth, Eleventh, and Twelfth streets before and after the completion of the main. A plat of the main showing the positions of its connections, main valves, air valves, and blow-off valves, is herewith.

The work of laying the new 30-inch main in New Jersey avenue was commenced on the 14th of November, 1890, and finished on the 16th of January, 1891. It is 4,410 feet, or rather more than three-fourths of a mile, long. It connects at L street with the 48-inch main and at B street with both the old 30-inch main in B street and the new 30-inch main leading through the Capitol grounds and East Capitol street to Eleventh street east. This main being entirely for the benefit of Capitol Hill, no connections were made with the District's distribution system anywhere on its route. Air valves were placed at B, I, and L streets and 12-inch blow-offs at D and K streets; 568 feet of the line extending southerly from L street was composed of 36-inch pipes, turned over to the United States for the purpose by the Commissioners of the District of Columbia. A 36-inch valve was placed at L street and three 30-inch valves were placed in the main and its branches at B street. A 30-inch by 12-inch Y was inserted in the main at F street, with the 12-inch outlet laid to the eastward for future use and closed with a bonnet. The gain in pressures on Capitol Hill by the use of the new main is shown in a table appended to this report, and a plat of the line is also herewith.

When the Eleventh street main and the New Jersey avenue main, just mentioned, had been completed, it was decided, as there yet remained of the appropriation sufficient money for the purpose, to lay a 24-inch main in K street NE., extending as far as Eleventh street. This was done for the purpose of increasing the supply to northeast Washington, which is rapidly increasing in population, and at the earnest solicitation of the District government. The necessary contracts were entered into and the work of laying the main, which commenced on the 24th of April, 1891, was completed on the 13th of June. It is 6,760 feet or about 1¼ miles long, and is supplied through the by-pass at New Jersey avenue and L street from the 36-inch main. It passes down New Jersey avenue under its eastern foot-way to K street, in which, with the exception of the block between North Capitol street and First street east, it is laid under the roadway. It crosses under the Baltimore and Ohio Railway between Seventh and Eighth streets and under the Metropolitan Branch of the same railway at First street east. With the coöperation of the railway officials, I was able to make such arrangements for these crossings that delays in the regular passage of the trains

were avoided. Air-valves were placed at New Jersey avenue and L street, at Third street, and at Eleventh streets east. Twelve-inch blow-offs were placed at North Capitol street and at Sixth street east. A 3-inch blow-off was also placed 400 feet west of First street east, to drain the water from a depression that exists in the block between that street and North Capitol street. Connections were made with the District's distribution system at all the street intersections from First street west to Eleventh street east, both inclusive. Three main valves were inserted in the line, viz, one on either side of the provision for a connection with the District's 12-inch main at Fourth street east and one at Eleventh street east. A table showing the pressures in the vicinity of the main before and after its completion and a plat of its route are herewith.

In addition to the foregoing there was completed early in the last fiscal year the following work connected with the 48-inch main that remained to be done at the beginning of the year, viz, filling over the 48-inch connection with the auxiliary gate-house and by-conduit at the distributing reservoir; the construction of the masonry well for the stop timbers for controlling this connection; the completion of the laying of the new service pipes in M street, Georgetown, between Twenty-ninth and Thirtieth streets, to enable the service pipes connected with the 12-inch main, which endangered the foundation of the 48-inch main, to be cut off; the placing in Twenty-ninth street, just above M street, of a valve in the old forcing main leading from the west abutment of Rock Creek Aqueduct Bridge, under the 48-inch main to the high-service reservoir on Road street,* and the rebuilding of the Canal road of the portion of the wall of the Chesapeake and Ohio Canal which fell under the weight of the 48-inch pipes deposited on the side of the road before they were laid in the trench.

The laying of the 24-inch main in K street NE. completed the work under the appropriation of March 2, 1889, and, as will be observed in the money statement at the end of this report, there is a remainder of the appropriation of $10,669.91 which can be reverted to the Treasury to the credit of the surplus fund.

Details of the expenditures of the appropriation of $575,000 March 2, 1889, for the 48-inch main.

Water pipe (23,250,000 pounds)	$282, 148. 22
Labor and other services, including teams	123, 427. 33
Special castings (1,450,000 pounds)	34, 578. 86
Replacing asphalt and stone block pavements	34, 099. 30
Valves	20, 246. 02
Lead and jute	16, 306. 62
Opening trenches (contract work)	10, 359. 81
Hauling pipe, castings, and valves	9, 325. 16
Tools and implements and repairs of same	7, 055. 88
M street bridge for 48-inch main	6, 629. 05
Lumber	4, 221. 35
Cement, sand, and gravel	3, 987. 76
Brick and stone	3, 800. 29
Hauling away surplus earth (contract work)	1, 942. 98
Screen at distributing reservoir	1, 168. 30
Stationery, advertising, and job printing	975. 47
Iron, nails, and spikes	843. 17
Plumbers' supplies	717. 24
Traveling expenses	633. 53
Forage and horseshoeing	513. 13

* The forcing main is not likely to be used again and the valve is to be kept shut.

Coke, coal, and wood	$380.46
Pitch, tar, and paint	128.30
Miscellaneous	841.86
Remainder	10,669.91
Total	575,000.00

The following table shows the location and lengths of mains laid by means of the act of March 2, 1889, providing for the construction of the 48-inch main, and the total lengths of these mains, viz, 45,293 feet, or about 8½ miles:

Size of main.	Location.		Length.
			Feet.
48-inch	From the distributing reservoir to Fourth street NW		22,888
		Feet.	
30-inch	East Capitol street	5,695	
30-inch	New Jersey avenue NW	4,410	
24-inch	Eleventh street NW	5,142	
24-inch	K street NE	6,760	
24-inch	Eighteenth street, between K and L streets NW	398	
			22,405
	Total		45,293

The following plans are sent with this report:

Plan of 24-inch main in Eleventh street NW.
Plan of 30-inch main in New Jersey avenue NW.
Plan of 24-inch main in K street NE.
Plan of M Street Aqueduct Bridge.
Plan of the chambers under M street, Georgetown, between Twenty-ninth and Thirtieth streets, containing the valves on the 48-inch, 36-inch, and 30-inch mains, and the 36-inch and 30-inch valves on the cross connections.

The plans of the 48-inch main and the 30-inch main on Capitol Hill were printed with the last Annual Report. The plans of the Eleventh street, New Jersey avenue, and K street east mains that are herewith show the positions of their cross connections with the District's distributing system and of their main valves, air valves, and blow-off valves, etc., and will be valuable for future reference.

I am indebted to Mr. Simon Newton, chief clerk, for his untiring labor in the preparation of the accounts of my heavy disbursements during the year; also to my other office employés and to Mr. Charles W. Cunningham, foreman of laying mains, and to my other foremen, for their enthusiastic and faithful services. Mr. Fitzgerald, of the District water office, again rendered valuable assistance in making connections between the new mains and the District's distributing mains.

The following is a money statement for the fiscal year ending June 30, 1891:

July 1, 1890, balance unexpended	$125,387.65
June 30, 1891, amount expended during fiscal year	114,521.07
July 1, 1891, balance unexpended	10,866.58
July 1, 1891, outstanding liabilities	196.67
July 1, 1891, balance available	10,669.91

No estimate for further appropriation is submitted.

Pressures obtained on Tenth, Eleventh, and Twelfth streets NW., before and after the laying of the 24-inch main in Eleventh street NW. in October and November, 1890.

Locality.	Before.	After.	Gain.	Gain of head.
	Pounds.	*Pounds.*	*Pounds.*	*Feet.*
Tenth and Q streets	20	23	3	6.9
Tenth and P streets	17	20	3	6.9
Tenth and O streets	13	18	5	11.5
Tenth and N streets	10	16½	6½	14.9
Tenth and M streets	13	20½	7½	17.2
Tenth and L streets	19	24	5	11.5
Eleventh and L streets	12	20	8	18.4
Eleventh and M streets	9	15	6	13.8
Eleventh and N streets	6½	13	6½	14.9
Eleventh and O streets	10½	14	3½	8.1
Eleventh and P streets	10½	17	6½	14.9
Eleventh street and Rhode Island avenue	11½	18½	7	16.1
Twelfth and L streets	11½	17½	6	13.8
Twelfth street and Massachusetts avenue	11	16	5	11.5
Twelfth and M streets	11	17	6	13.8
Twelfth and N streets	9	15½	6½	14.9
Twelfth and O streets	10	16	6	13.3
Twelfth street and Rhode Island avenue	11	17	6	13.8
Twelfth and Q streets	11	17½	6½	14.9

Pressures taken on Capital Hill on January 15 and 16, before and after turning the water into the new 30-inch main on New Jersey avenue.

Locality.	Before.	After.	Gain.	Gain of head.
	Pounds.	*Pounds.*	*Pounds.*	*Feet.*
Second and East Capitol streets	11½	15½	4	9.2
Third and East Capitol streets	13	15½	2½	5.8
Fifth and East Capitol streets	15½	17½	2	4.6
Sixth and East Capitol streets	16	18½	2½	5.8
Seventh and East Capitol streets	19	21½	2½	5.8
Ninth and East Capitol streets	18	20½	2½	5.8
Eleventh and East Capitol streets	17	19	2	4.6
First and B streets east	19½	22	2½	5.8
Second and B streets east	15½	17½	2	4.6
Fourth and B streets east	17	19	2	4.6
Sixth and B streets east	14	17	3	6.9
Eighth and B streets east	17	19½	2½	5.8

Pressures on K, L, and M streets NE., before and after laying of the 24-inch main in K street NE.

Locality.	Before.	After.	Gain.	Gain of head.
	Pounds.	*Pounds.*	*Pounds.*	*Feet.*
Second and K streets	32	33	1	2.3
Sixth and K streets	34	36	2	4.6
Seventh and L streets	27	31½	4½	10.3
Sixth and L streets	29	31½	2½	5.7
Fifth and M streets	15	21	6	13.8
Fifth and L streets	28	31	3	6.9

List of blow-off valves, air valves, and vacuum valves on the main in Eleventh street NW., on the new main in New Jersey avenue NW., and on the main in K street NE.

Location.	Size.	Location.	Size.
Blow-off valves:	*Inches.*	Air valves:	*Inches.*
Eleventh and Q streets NW	10	New Jersey avenue and I street NW	4
New Jersey avenue and K street NW.	12	New Jersey avenue and B street NW.	4
New Jersey avenue and D street NW.	12	K and Third streets NE	4
K and North Capitol streets	12	K and Eleventh streets NE	4
On K street between North Capitol street and First street east	3	3-inch vacuum valves:	
K and Sixth streets NE	12	Eleventh and U streets NW*	
Air valves:		Eleventh and N streets NW	
Eleventh and U streets NW	4	Eleventh and Massachusetts avenue (2 valves)	
Eleventh and N streets NW	4	New Jersey avenue and L street NW. (2 valves)	
Eleventh and M streets NW	1	New Jersey avenue and I street NW	
Eleventh and Massachusetts avenue NW	8	New Jersey avenue and B street NW.	
Eleventh and Massachusetts avenue NW. (2 valves)	4	K and Third streets NE	
New Jersey avenue and L street NW. (2 valves)	4	K and Eleventh streets NE	

NOTE.—A 12-inch blow-off valve was placed on the old 30-inch main in New Jersey avenue at D street NW. All the 4-inch air valves open downward, so that being always kept a little open they prevent accumulations of air at the summits of the mains.

List of main valves placed in the main in Eleventh street NW., in the new main in New Jersey avenue NW., and in the main in K street NE.

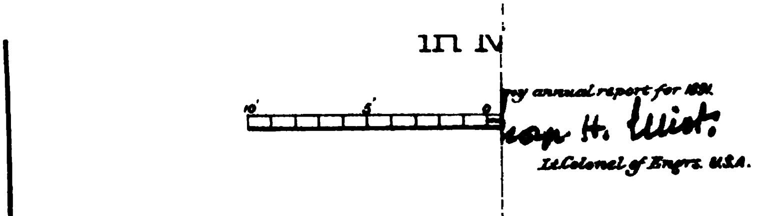
Location.	Location.
36-inch valve.	*24-inch valves.*
New Jersey avenue and L street northwest.	Eleventh and U streets northwest.
30-inch valves.	Eleventh and R streets northwest (2 valves).
New Jersey avenue and B street northwest (3 valves).	Eleventh and Massachusetts avenue northwest, (2 valves).
	K and Fourth streets northeast (2 valves).
	K and Eleventh streets northeast.

Abstract of proposals for cast-iron water pipe and special castings received in response to advertisement by circular letter dated June 19, 1890, and opened July 1, 1890, by Lieut. Col. George H. Elliot, Corps of Engineers.

ABSTRACT FOR STRAIGHT PIPE.

No.	Name and address of bidder.	Size.	Price per ton.	Total amount of bid.
1	Gloucester Iron Works, of Philadelphia, Pa	24 and 30	$27.56	$36,100.77
		12	27.42	
		10	27.78	
		6	28.21	
		4	29.58	
		3	32.29	
2	Mellert Foundry and Machine Co. (limited), of Reading, Pa		26.80	* 35,091.38
3	Camden Iron Works, of Philadelphia, Pa		26.40	34,567.63

* Contract made. The lowest bid did not comply with the specifications in respect of time of completion.



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my annual report for 1891.
Geo. H. Elliot
Lt.Colonel of Engrs. U.S.A.

Eng 91

Abstract of proposals for cast-iron water pipe and special castings, etc.—Continued.

ABSTRACT FOR SPECIAL CASTINGS.

No.	Name and address of bidder.	Description.	Price.	Total amount of bid.
			Per lb.	
1	Gloucester Iron Works, of Philadelphia, Pa	Y branches	$0.05	$3,989.07
		24, 30, and 36 inch straight branches and turns	.04½	
		Branches and bends below 24-inch	.03	
		Sleeves	.02½	
		Valve casings and covers	.03½	
		Manhole frames and covers	.03	
		All flange work	.05	
			Per ton.	
2	Camden Iron Works, of Philadelphia, Pa		$60.00	3,000.00
3	McNeal Pipe and Foundry Co., of Burlington, N. J		52.50	2,625.00
4	Mellert Foundry and Machine Co. (limited), of Reading, Pa		52.40	*2,620.00

* Lowest bid; contract made.

Abstract of proposals for hauling pipe, special castings, and valves received in response to circular letter dated July 1, 1890, and opened July 11, 1890, by Lieut. Col. George H. Elliot, Corps of Engineers.

No.	Name and address of bidder.	Price per ton.	Total amount of bid.
		Cents.	
1	George W. Knox, of Washington, D. C	*70	$840.00
2	Springmann & Brother, of Washington, D. C	72	864.00

* Lowest bid; contract made.

Abstract of proposals for 24-inch water pipe and special castings, received in response to circular letter dated February 19, 1891, and opened March 3, 1891, by Lieut. Col. George H. Elliot, Corps of Engineers.

ABSTRACT FOR 24-INCH PIPE.

No.	Name and address of bidder.	Price per ton.	Total amount of bid.
1	Camden Iron Works, of Philadelphia, Pa	*$23.80	$18,492.60
2	Howard Harrison Iron Company, of Bessemer, Ala	24.43	18,982.11
3	Mellert Foundry and Machine Company, limited, of Reading, Pa	25.60	19,891.20
4	Gloucester Iron Works, of Gloucester City, N. J	25.75	20,007.75

ABSTRACT FOR SPECIAL CASTINGS.

1	Camden Iron Works, of Philadelphia, Pa	*23.80	595.00
2	Howard Harrison Iron Company, of Bessemer, Ala	54.93	1,373.25
3	Mellert Foundry and Machine Company, limited, of Reading, Pa	50.00	1,250.00
4	Gloucester Iron Works, of Gloucester City, N. J	90.00	2,250.00

* Lowest bid; contract made.

Abstract of proposals for hauling pipe, special castings, and valves received in response to circular letter dated March 6, 1891, and opened March 11, 1891, by Lieut. Col. George H. Elliot, Corps of Engineers.

No.	Name and address of bidder.	Price per ton.	Total amount of bid.
		Cents.	
1	George W. Knox, of Washington, D. C.	*65	$520.00
2	Springmann & Brother, of Washington, D. C.	68	544.00

* Lowest bid; contract made.

D D D 3.

INCREASING THE WATER SUPPLY OF WASHINGTON, DISTRICT OF COLUMBIA.

This work was commenced under an appropriation made in the act of Congress approved July 15, 1882.

The plan consisted of raising the dam in the Maryland channel at the Great Falls of the Potomac to an elevation of 148 feet above mean tide at the Washington navy-yard, and its extension at that height across Conn's Island and the Virginia channel of the river; extending the Washington Aqueduct from the distributing reservoir above Georgetown ot the site selected for the new reservoir near Howard University by a tunnel 20,696.3 feet long; constructing at the tunnel outlet a new reservoir of about 300,000,000 gallons capacity, and connecting this reservoir by a new line of large mains with the existing system of water mains in the city of Washington.

All operations on this project are suspended, and no work has been done under it during the year.

The timber lining of the Foundry Branch shaft, which had become decayed, gave way last fall during a rainy period to a depth of about 30 feet below the surface of the ground (or to the point where the shaft entered the rock), and the broken timber and supported earth fell to the bottom of the shaft, filling it to an unknown depth.

The falling of the lining at this shaft led to an examination of all the other shafts except Rock Creek shaft, and it was found that the upper part of the lining of each of them should be renewed for the purpose of preventing damage to the shafts as at Foundry Branch.

Rock Creek shaft is, and has been for a long time, filled with water, so that it is probable that the timbering in it has not decayed.

The work of renewing the lining, which could not be done in winter when the ground around the shafts was saturated with water on account of the danger of slips, was commenced in March, and has been prosecuted as fast as the weather would allow till the end of the fiscal year, when the lining of the Foundry Branch shaft had been completed and the one at Champlain avenue had been nearly completed. The work consisted in making an entirely new lining of the best quality of Georgia pine, either from the surface of the rock or from the top of the brick lining that had been carried at the west shaft near the distributing reservoir to a depth of about 10 feet, and at the Howard University shaft to a depth of about 23 feet below the surface of the ground. The lining of the Foundry Branch and Champlain avenue shafts are entirely of wood. It is expected that the work at all the shafts, except Rock

Creek shaft, which, as before stated, is filled with water, will be entirely completed early in this fiscal year.

Several reports on the suit against the United States in the Court of Claims by Maloney and Gleason have been made during the year.

A watchman has been employed during the year at the new reservoir, and it being found that the piles of stone at the mouths of the shafts which have a market value and should be reserved for the use of the United States and the District of Columbia for the repairs of roads, was being depredated upon by contractors for private work, his duties have included the guarding the stone at the mouths of all the shafts, except the one at Foundry Branch, which is under the care of the watchman at the distributing reservoir.

The following is a list of appropriations for this work, with date of act for the same:

July 15, 1882	$1,485,279.30
July 7, 1884	87,500.00
March 3, 1885	87,500.00
March 26, 1886	5,000.00
August 4, 1886	555,000.00
March 30, 1888	355,000.00
Total	2,575,279.30

The following is a money statement for the fiscal year ending June 30, 1891:

Title of appropriation.	Amount unexpended, July 1, 1890.	Amount expended during fiscal year, June 30, 1891.	Balance unexpended, July 1, 1891.	Outstanding liabilities, July 1, 1891.	Amount available July 1, 1891.
Land to extend aqueduct	$24,930.49		$24,930.49		$24,930.49
Extension of aqueduct	276,229.09	$2,261.75	273,967.34	$1,183.18	272,784.16
Main connections	1,989.18		1,989.18		1,989.18
Land for reservoir	173.09		173.09		173.09
Constructing reservoir and gate house	83,739.13	554.32	83,184.81	148.64	83,036.17
Water rights and land to extend dam at Great Falls	44,882.04		44,882.04		44,882.04
Completion and extension of dam at Great Falls	4,665.52		4,665.52		4,665.52
Aggregate	436,608.54	2,816.07	433,792.47	1,331.82	432,460.65

No estimate for further appropriation is submitted.

D D D 4.

ERECTION OF FISHWAYS AT GREAT FALLS.

Plans and specifications for a new system of fishways, the first of which is to be erected at Great Falls, having been prepared by the Commissioner of Fish and Fisheries as contemplated by the act making appropriations for the fishways, proposals for their construction, which had been extensively advertised for, were opened on the 1st of June, 1891. Mr. Isaac H. Hathaway, of Philadelphia, Pa., was the only bidder, and, with the approval of the Chief of Engineers, a contract, which

is to be finished on or before the 12th of November, 1891, was entered into with him on the 9th of the same month.

The plans and specifications appear to be judicious and well adapted to the site of the work, which is doubtless more difficult than any other to which, if successful, they are likely to be applied in this country.

By direction of the Secretary of War the construction will be carried on under the direction of the Commissioner above mentioned, the engineer officer in charge being held responsible only for the proper protection of the Aqueduct Dam at Great Falls and for the disbursement of the funds appropriated.

The only expenditures during the year were for advertising and the printing of the plans and specifications.

The appropriations for this work to date are as follows:

Act of July 15, 1882	$50,000.00
Act of February 1, 1888	25,000.00
Total	75,000.00
Total disbursements to June 30, 1891	45,125.82
Balance unexpended	29,874.18

The following is a money statement for the fiscal year ending June 30, 1891:

July 1, 1890, balance unexpended	$30,020.32
June 30, 1891, amount expended during fiscal year	146.14
July 1, 1891, balance unexpended	29,874.18
July 1, 1891, amount covered by uncompleted contract (about)	28,520.32
July 1, 1891, balance available	1,353.86

The Commissioner of Fish and Fisheries is of the opinion that in addition to the funds available the sum of $15,000 will be required to complete the fishway at Great Falls, and an estimate for an appropriation of this amount is recommended and submitted.

Abstract of proposals for construction of fishways at Great Falls of the Potomac, received in response to advertisement dated May 1, 1891, and opened June 1, 1891, by Lieut. Col. George H. Elliot, Corps of Engineers.

1. Isaac H. Hathaway, of Philadelphia, Pa.:

Earth excavation	per cubic yard	$0.85
Solid rock excavation	do	4.00
Bowlder excavation	do	3.00
Concrete masonry	do	7.50
Riprap	do	2.00
Superstructure of section 2		3,100.74
Superstructure of section 3		2,960.44
Superstructure of section 4		3,150.03
Superstructure of section 5		7,382.43
Reconstructing section 6		4,900.87
Rubble-stone masonry in section 1	per cubic yard	12.00
Timber and lumber in section 1	per M feet, B. M.	130.00
Cast iron in section 1	per pound	.[illegible]
Wrought iron and steel in section 1	do	.[illegible]
Rubble-stone masonry, not including section 1	per cubic yard	6.
Coping in entire work	do	80.
Timber and lumber, not included in superstructures of sections 1, 2, 3, 4, 5, and 6	per M feet, B. M.	65.
Wrought iron, steel, etc., not included in superstructures of sections 1, 2, 3, 4, 5, and 6	per pound	.
Total amount of bid, estimating the quantities as per specifications		31,908.

Only bid; contract made. Amount limited to funds available.

APPENDIX E E E.

IMPROVEMENT AND CARE OF PUBLIC BUILDINGS AND GROUNDS IN THE DISTRICT OF COLUMBIA—WASHINGTON MONUMENT.

REPORT OF COLONEL OSWALD H. ERNST, U. S. A., OFFICER IN CHARGE, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

OFFICE OF PUBLIC BUILDINGS AND GROUNDS,
Washington, D. C. July 10, 1891.

GENERAL: I have the honor to submit the following report of operations upon public buildings and grounds under the Chief of Engineers in the District of Columbia, including the care and maintenance of the Washington Monument, during the fiscal year ending June 30, 1891:

MAINTENANCE OF IMPROVED PARKS.

The care required to maintain the various improved parks and park places in good condition has been extended during the year. The operations have consisted in mowing and raking lawns and destroying weed growth upon them, scuffling, raking, dressing, and rolling gravel walks and edging their margins, cleaning gutters and drain traps, pruning trees and shrubs and removing web caterpillars and bag worms from them, maintaining pavements and asphalt roadways and walks in a cleanly condition, trimming and caring for flower beds and inclosing them with light wire fences where necessary. In the autumn some of the beds were planted with early spring flowering bulbs and others with chrysanthemums for fall blooming. In May and June the beds and vases were stocked with flowering and ornamental foliage plants for summer decoration and the basins of fountains were planted with water lilies.

GROUNDS SOUTH OF EXECUTIVE MANSION.

Worn portions of the 50-foot roadway around the central ellipse in these grounds were resurfaced during the year, 637 cubic yards of unscreened gravel having been used for the purpose. A number of young trees and shrubs were planted to fill vacancies in some of the groups, and they were staked and wired. A wagon shed was erected in the rear of the President's stable, located within the grove of trees in the northwest corner of the grounds.

WASHINGTON NATIONAL MONUMENT.

The monument has been open to visitors daily, Sundays and holidays excepted, and the elevator has been run every day that the monument was open, with the exception of one day, July 1, 1890, when the old supply of fuel had been exhausted and a new supply under the new appropriation had not yet been delivered, and four and one-half days in September—25 to 30—when it became necessary to stop running the car for the purpose of making repairs. Monthly inspections of the elevator and its machinery were made by an agent of the builders, and daily inspections were made by the employés at the monument before starting to carry passengers. There were 159,160 visitors to the top of the shaft during the year, of which number 113,149 made the ascent in the elevator and 46,011 by the stairway, making a total of 456,305 persons who have visited the top since the monument was opened to the public on October 9, 1888. The grooves in the main sheave at the top of the shaft, worn by the wire ropes attached to the car, were turned out, the safety appliances were overhauled, cleaned, and replaced, and a new battery for operating the annunciator in car was placed in position. Minor carpentry repairs were made as needed, and the usual care required to maintain the interior of the shaft and its surroundings in a neat condition was extended. Numerous acts of vandalism occurred during the year, and arrests were made whenever the perpetrators were detected. These acts consist principally in writing upon the walls and chipping pieces from the memorial blocks. The most flagrant acts of this character were the breaking of a letter from one of the memorial stones and the removal of one of the silver letters from the "Nevada" stone. New wire for the service of the electric lamps was run between the lower floor and the 100-foot landing and new lamps put up. The heater pipes on lower floor of shaft, and the boiler and pipes in lodge, were given a coat of asphaltum, and the boiler in lodge was overhauled, new valves and water-gauge glass put on, and a new trap placed in floor of boiler pit to prevent flooding by backwater from main sewer during storms. The tin roof covering of this lodge was repaired and repainted.

During a severe windstorm on December 17, nearly one-half of the copper covering of roof of engine house was torn up and so bent and twisted as to require replacing with new materials. The necessary repairs were made and the roof repainted. The piston rods of elevator engine were repacked, the crank pin boxes of dynamo engine rebabbitted and each of the two armatures of dynamo fitted with a new commutator. The boilers were maintained in good condition, a new steam-tube cleaner purchased for their use, some new joints made upon the main steam pipe between boilers and engines, and part of the drain from boiler house was taken up, cleaned and relaid.

WASHINGTON MONUMENT GROUNDS.

The work of grading the low grounds north of the shaft has been continued during the year and satisfactory progress has been made, the rough grading being nearly completed. The greater portion of the filling used in this work has been obtained without cost to the United States, about 25,087 cubic yards of earth and clay having been received from various contractors who found this park a convenient dumping place. Some material for this grading was also received from work in progress upon other portions of the public grounds. About 350 cubic yards of gravel and 320 loads of brickbats, old concrete, etc., were also

received from various persons, without cost, and piled for future use in constructing roads and walks. Portions of the ground along roadway south of lodge house, and 2 manholes, were raised to conform to grade, and the work of constructing the new roadway connecting the monument with main roadway on west side of grounds was completed, the ground bordering the same graded, seeded, and part of it sodded; 1,480 linear feet of cobblestone gutters, 2½ feet wide, were constructed along the margins of this roadway, 11 additional brick drain-traps built, and 150 feet of 6-inch and 245 feet of 8-inch terra cotta drain-pipe laid to connect them with the main drain. A new roadway north of the monument, to connect with that on the west, was outlined, and 975 linear feet of it excavated, bottomed with broken stone and brick, and covered with a first coating of gravel, and the ground on the south side of the roadway was given a coating of compost and soil to finish the grade, about 324 cart loads of material being used for the purpose. A new walk was also constructed commencing on the north side of the monument and running northwest to the roadway opposite the carp ponds, and an asphalt pavement covering an area of 377 square yards was laid upon the same. The soil excavated in constructing this new walk was used in surfacing trespass paths across the lawns, which were then sown down in grass seed.

GREENHOUSES AND NURSERY.

There are 16 greenhouses in the nursery grounds, numbered from 1 to 16, and covering an area of 24,787 square feet. House No. 16 was constructed during the fiscal year. It is to be used as a propagating house; is 120 feet long, 12 feet wide, and 9½ feet high; the brick walls are 4½ feet high and 9 inches thick; the house is heated by a brick furnace at each end, with the necessary iron and terra cotta hot-air flues. The other buildings in the nursery grounds are 2 brick potting sheds, 7 frame buildings used as shops and storehouses, 1 large lath house used for storing plants in summer, and 2 open sheds. There are also 648 feet of cold frame, 6 feet wide. One of the seven frame buildings was constructed during the fiscal year. It is a 2-story structure, 35 feet long, 25 feet wide, and 16 feet high; the first story will be used for storing coal, and the second as a carpenter shop and storeroom. The building was not quite completed at the close of the fiscal year, the work remaining to be done consisting of the laying of the wooden floor of the first story and the shingling of the south side of roof. Necessary repairs were made to the several greenhouses during the year. The entire superstructure of house No. 5 was removed, and rebuilt with new material, and the brick foundation walls repaired. In 9 of the greenhouses 1,514 linear feet of old staging 3 and 4 feet wide was torn out and replaced with new material; 121 feet of new sills, 152 feet sheathing, 200 feet of beading, 22 new side posts, and 2 new rafters put in; 744 feet of grooved strips placed on rafters to prevent drip, and 36 posts and 100 feet of 7-inch gutter repaired. The brick walls of 4 greenhouses were repointed, and five houses were reglazed; in houses numbered 1 and 2 the brick arches and flues of 2 boilers were opened, cleaned, and the brickwork rebuilt, and a brick and stone water tank 20 feet long, 4 feet wide and 14 inches deep, built across the ends of the houses for use in wintering aquatic plants. The roof of house No. 9 was braced with 190 feet of three-quarter-inch iron rods. House No. 10 was provided with 10 new rafters, 32 rabbeted strips, and 200 feet of 12-inch ridge boards; and 4 brick piers to support hot-water pipes

were built in house No. 13. The flues of all boilers and furnaces were opened and cleaned; leaky joints on hot-water pipes recalked; all repaired woodwork in the several greenhouses was given 3 coats of paint, and 2,400 linear feet of additional shelving for the accommodation of bedding plants put up. An entire new framework was placed on a brick pit 75 feet long and 6 feet wide; a plant bench 33 feet long and 6 feet wide constructed; 1,200 square feet of the tin roof covering of potting sheds, and 234 feet of cold frame 6 feet wide repaired; 4 large frame storehouses and shops, and 304 linear feet of paling fence given two coats of insecticide wash; and 18 plant tubs and 515 plant boxes constructed. In January the brick chimney of one of the potting sheds fell, doing some damage to two adjoining greenhouses; the chimney was rebuilt and the damage repaired.

During the autumn of 1890 about 7,000 chrysanthemums were sent out for planting in the various parks. There were planted in the greenhouses, for winter bloom, 1,484 roses, 1,116 smilax, 219 heliotrope, 2,752 carnations, 424 begonias, 441 alyssum, 70 rose geraniums and 69 abutillons, a total of 6,575 plants, and for winter forcing there were potted and boxed 2,121 Roman hyacinths, 1,568 narcissus, 5,000 convallaria majallis, 2,000 Dutch hyacinths, 2,500 tulips, 500 scilla siberica, 210 clumps of spirea japonica, and 3,560 miscellaneous bulbs; in all, 17,459. For early spring bloom there were planted 483 lilium auratum bulbs, and in the cold frames 800 violets and 497 pansies. There were purchased during the year 1,365 plants for the greenhouses and 49,700 bulbs for setting out in the parks and as stock for the nursery. During the winter and early spring months about 402,000 ornamental foliage and flowering plants, divided into 330 varieties, were propagated, nearly all of which were set out in the parks during May and June.

In the nursery the grounds were maintained in a neat and cleanly condition, attention bestowed upon the stock growing therein, and necessary transplanting done as required; 277 young trees and 346 flowering shrubs were purchased and set out in nursery rows for acclimation before final planting in the public grounds. During the year 217 young trees and 1,189 shrubs were lifted and planted in various parks. There were planted in the nursery for stock, 7,883 carnations, 500 geraniums, 420 acacias, 465 acquilegias, 1,082 tropical and 465 bedding plants, and the following bulbs: 3,500 tuberose, 520 gladiolas, 300 cannas, and 90 dahlias; the privet hedge along the west boundary was pruned, 100 feet of arbor vitæ hedge planted at northwest corner of grounds, and 13 flower beds on the lawn in front of north fence were planted in May; 162 feet of 2-inch and 80 feet of 1¼-inch galvanized iron waterpipe were laid in the grounds to afford additional irrigating facilities.

SMITHSONIAN GROUNDS.

The area of asphalt pavement in this park was extended by the construction of 1,824 square yards of asphalt roadway and 320 square yards of asphalt footwalk upon the gravel roadway leading from the west end of Smithsonian Institution to the park entrance at Tenth and B streets, NW., the gravel excavated in preparing for this work, about 450 loads, was used in resurfacing worn-down portions of other roadways in the park. A new gravel walk was constructed near the Ninth-street entrance on north side of grounds, where a footpath had been formed across a short stretch of lawn surface, and two new brick drain traps were constructed, one at each end of the walk and connected with existing drains. The old walks adjoining this new one were resur-

faced with fresh gravel. A new short gravel walk was also constructed in the southwest portion of the grounds leading from one of the main walks to the stable of the Smithsonian building. The margins of both of these new walks were sodded, the lawn surface on either side sown down in grass seed, and an additional brick drain-trap constructed near the National Museum Building.

HENRY AND SEATON PARKS.

In Henry (Armory) Park an asphalt footwalk, containing an area of 257 square yards, was laid upon the gravel path leading from the east entrance to the U. S. Fish Commission building to Seventh street, and a brick drain-trap constructed to carry off surface water. A temporary plank footwalk 160 feet long was laid during the winter upon wet portions of the gravel path leading from B street, near the railroad depot, to Seventh street.

In Seaton Park 136 cubic yards of gravel was used in resurfacing worn portions of the footpaths.

RESERVATION NO. 162.

The act of Congress approved December 15, 1890 (vol. 26, Statutes, p. 690) authorized the Commissioners of the District of Columbia to use and occupy this reservation, situated at the intersection of Ohio avenue with Fourteenth and C streets NW., as a site for a truck-house, and on December 20 the Commissioners requested the early removal of the fence, shrubs, etc., as they were desirous of commencing the construction of the building. The iron post and chain fence was, accordingly, taken down and removed to the storage yard in the nursery, the trees and shrubs were lifted, and the top soil excavated to a depth of 14 inches and hauled to the Monument grounds. This work was completed early in January, when the reservation was transferred to the custody of the Commissioners.

IOWA CIRCLE.

This circle, situated at the intersection of Rhode Island avenue with Thirteenth and P streets, NW., was entirely remodeled during the year. The old asphalt walks were excavated and removed, the openings left thereby filled in with earth and clay, surfaced with top soil to bring them to the grade of the surrounding lawns, and sodded and sown down in grass seed. New walks were constructed upon more direct lines of travel and an asphalt pavement laid upon them, covering an area of 2,097 square yards. Such portions of the material excavated from the old walks as were needed for the purpose were used in constructing the new walks, and the remainder was hauled to the Monument grounds. The borders of the new walks were sodded and 168 jasminum nudiflorum shrubs planted over the lawn surfaces. The changes made in the walks necessitated the removal of the two drinking fountains in the circle and they were taken down, re-erected in new locations and reconnected with water supply and waste pipes.

JUDICIARY SQUARE.

The work in progress for the improvement of this park was continued during the year. About 1,000 linear feet of additional cobble-stone

gutters 2 feet wide and 343 linear feet of additional brick gutters 1 foot wide were laid along the margins of gravel roads and walks; 6 new brick drain-traps constructed, and 286 linear feet of 8-inch and 86 linear feet of 6-inch terra cotta drain-pipe laid to connect them with main drains; 278 linear feet of brick gutters were taken up and relaid, and extensive repairs made to the gravel roads and walks, 114 cubic yards of rough gravel and 220 cubic yards of screened gravel being used in resurfacing worn portions of them. An apron of granite blocks was laid across the concrete pavement from roadway on line of E street to roadway leading to west entrance of court-house; bare places on the lawns bordering roads and walks in southeast corner of grounds were resodded; the cobblestone pavement at entrance to coal vaults on east side of Pension Office building was repaired; a granite block gutter 36 feet long and 3 feet wide laid in front of the pavement, and a drain lodge built at end of gutter and connected by 18 feet of 6-inch drain pipe with main drain for the purpose of carrying off surface water which laid at that point during heavy rains. A hedge of privet was planted around the watchman's lodge in the place of one composed of arbor vitæs, which had died; the water supply of closets in lodge was increased by the introduction of survice pipes of larger size, the two old urinal bowls removed and replaced with new ones, and the old slate lining put back in position; 206 square yards of new asphalt pavement were laid on the east side of the Pension Office building, and 747 square yards of new asphalt footwalk were constructed upon the gravel path leading from near the southeast corner of that building through the park to near the northwest corner of the court-house. Portions of the sodded borders of roads and walks were lowered, additional groups of young trees and shrubbery planted, 10 feet of granite curbing set at entrance of roadway from Fourth and E streets, and 390 square yards of asphalt footwalk through the park on the line of this roadway were resurfaced.

RESERVATIONS NORTH OF PENNSYLVANIA AVENUE AND WEST OF THE CAPITOL.

In Franklin Square the Chinese arbor vitæs composing the hedge screening a portion of the watchman's lodge having died, they were removed and replaced with a hedge of privet; the drain pipe from water-closets was taken up and replaced with a new 6-inch terra-cotta pipe drain 180 feet in length, and 217 square yards of asphalt footwalk were resurfaced.

In Lafayette Square the old public urinals in the watchman's lodge were torn out, the floors of closet laid in slate, 3 new urinals with new water supply and waste pipes put in, and a slate wainscoting put up on the walls, with slate partitions separating the bowls. The walls in the watchman's room were wainscoted in wood a distance of 4 feet from the floor, the woodwork oiled, and the doors repainted; 330 square yards of asphalt footwalk were resurfaced, portions of the gravel paths bordering them repaired with fresh gravel, and uneven portions of brick gutters taken up and relaid. Bare spaces on the lawns at southeast corner of the park, where grass will not grow owing to the dense shade of the trees, were planted with hardy ivy and vincas, and in May a large and handsome group of palms and other foliage plants was made at the central entrance from Pennsylvania avenue upon the site originally selected for the statue to General Lafayette, and which was left bare by the removal of the granite sub-base of the pedestal of that statue.

Reservation No. 158, at the intersection of New York avenue, First, and M streets NW., which was cut down to the grade of the surrounding streets during the fiscal year ending June 30, 1890, has been further improved during the fiscal year 1890-'91. The ground has been rough graded, surfaced with manure and good soil, the borders sodded, several groups of young trees and shrubs planted, and the reservation inclosed with a post-and-chain fence, being a portion of that formerly inclosing Iowa Circle.

The asphalt footwalks in McPherson Square having become so much worn as to permit water to lie upon their surfaces during wet weather, temporary plank walks were laid upon them during the autumn of 1890 and removed in the spring of 1891.

In Farragut Square 150 square yards of asphalt footwalks were resurfaced.

In Mount Vernon Square about one-half of the gravel paths were resurfaced, 167 cubic yards of gravel having been used in making the repairs.

The brick gutter and flag pavement around Scott Circle were repaired where they had settled during heavy rains.

HANCOCK CIRCLE.

Pursuant to a provision in the District of Columbia appropriation act approved March 2, 1889 (vol. 25 Stats., p. 798), the Commissioners of the District of Columbia have established a circle at the intersection of New Hampshire avenue, Sixteenth and U streets NW., to be called "Hancock Circle." In a letter dated December 15, 1890, from the Commissioners they state that as this circle belongs to one of the classes of reservations now under the management of the office of Public Buildings and Grounds, it would seem proper that it should be under the same jurisdiction, and that they were willing to make the transfer. The Commissioners were informed that the transfer was accepted, and the reservation has been numbered 129½ and placed upon the plat book of the reservations belonging to the United States under the charge of this office.

STATUE TO MEMORY OF GENERAL LAFAYETTE AND HIS COMPATRIOTS.

On the 20th of November I was notified by the honorable the Secretary of War, through the Chief of Engineers, that a new site for this statue had been selected by the Commission at the southeast corner of Lafayette Square, and I was directed to proceed with the work of constructing a foundation for the pedestal of the statue. Work was at once commenced, an excavation of suitable size made, and a foundation of broken stone and Portland-cement concrete constructed; the granite stones composing the sub-base were removed from the original site at the south central entrance to the square, and by February they had been set in position upon the new foundation and an earth mound constructed around their base. In March the contractor's agent set the marble pedestal and in April placed the bronze figures in position, after which this office sodded the mound and inclosed it with a curb of dressed granite, reconstructed the gravel walks, and laid an asphalt footpath upon the walk at the north side of the statue. Two ornamental lamp-posts and lamps for illuminating the statue have been ordered and will be placed in position when received.

PUBLIC RESERVATIONS OCCUPIED BY THE BALTIMORE AND POTOMAC RAILROAD COMPANY AND THE BALTIMORE AND OHIO RAILROAD COMPANY.

Attention is again invited to the fact that without authority of law and in violation of section 223 of the Revised Statutes relating to the District of Columbia, the Baltimore and Potomac Railroad Company is now occupying reservations Nos. 101, 105, 109, 174, 177, 178, 241, and 309, and the Baltimore and Ohio Railroad Company is occupying reservation 201.

This office has reported from time to time the facts of the occupancy of some of these reservations by the railroad companies, and the subject has been referred to the law officers of the Government, with the request that such action may be taken as will be necessary for the protection of the interests of the United States.

RESERVATIONS EAST OF THE CAPITOL.

The iron posts of the fences inclosing Lincoln and Stanton Squares were straightened, and in the latter park 192 feet of temporary plank walk was laid over wet places on the gravel paths for the convenience of pedestrians during the winter and spring.

In Folger and Marion Parks and the reservation at Delaware avenue and First street NE. worn places in the gravel paths were resurfaced with fresh gravel, the greater portion of the walks in the park first named having required these repairs.

RESERVATION NO. 17, GARFIELD PARK.

Extensive repairs were made to the gravel roads and walks, about 1,400 cubic yards of unscreened and screened gravel being used for the purpose. The main roadway along the line of Virginia avenue, which is subjected to heavy travel, was resurfaced with broken stone and coarse gravel; in the eastern section of the park 3,179 linear feet of cobblestone gutters 3 feet wide have been constructed; 111 trees and 451 shrubs were planted, and necessary repairs made to the tool house; 4,500 cubic yards of gravel were received without cost to the United States from contractors engaged in improving streets and grading private ground in the vicinity, and this material has been stored upon the reservation for use in the various parks.

PARK SETTEES, COMPOST, TOOLS, AND REMOVING SNOW AND ICE.

One hundred new park settees were purchased during the year and about 200 old settees were repaired and repainted; irons for fastening down settees were made and loose settees in the various parks were refastened in position.

Seven hundred and fifty-one cubic yards of stable manure and 1,071 cubic yards of soil were purchased, thoroughly mixed, and the compost thus formed was spread upon the lawns of various parks during the winter and raked in in the spring.

The various tools and appliances used in prosecuting the work upon the public grounds were kept in good repair and purchases of new tools were made from time to time as required.

During the winter the snow and ice were removed from the walks through the various parks and the pavements surrounding them as promptly as possible after each storm.

CONSTRUCTING, REPAIRING, AND PAINTING IRON FENCES, PAINTING VASES, ETC.

The iron post-and-chain fence around Iowa Circle was removed and a portion of it used in inclosing the small reservation at the intersection of New York avenue, First and M streets, NW., Reservation No. 158; the iron posts of some of the parks were straightened and the chain tightened; about 240 new iron tops were placed on posts whose tops were broken or missing, and other necessary repairs were made to the iron fences as required.

The high iron fence of the grounds at the north front of the Executive Mansion, the lamp posts and lamps at that front and the large iron vases within the grounds, the post-and-chain fences of the four reservations on Pennsylvania avenue from Twentieth to Twenty-fourth streets, McPherson Square, and the lamp posts and vases therein, and the lamp posts in Lafayette and Farragut squares, were repainted, as were also the iron post-and-chain fences inclosing the following reservations: Du Pont Circle, Mount Vernon Square, and two reservations on the east and one on the west side of the square; reservations at Connecticut avenue and R streets, M street and Eighteenth and Twentieth streets, NW.; Massachusetts avenue, Twenty-first and Twenty-second streets; six reservations on Massachusetts avenue between Tenth and Twenty-first streets, NW.; one reservation east and one west of Iowa Circle; four on New York avenue between Tenth and Thirteenth streets, and one at New York avenue, First and M streets, NW.; three on Rhode Island avenue between Seventh and Tenth streets, and two on New Jersey avenue and I street NW.; reservation at North Carolina avenue and Ninth street SE., and portions of the fence inclosing Lincoln Square. Fourteen iron vases in various reservations, all repaired places in fences, and a number of small sign boards for use in the public parks, were painted.

WATER PIPES, FOUNTAINS, AND GAS LAMPS.

Attention was paid to the water pipes in the public grounds during the year, and such repairs made as were required. In the autumn the hose valves were removed from the pipes and stored in the nursery shops, and during the winter they were examined, and those requiring it repaired; in the spring they were replaced upon the pipes. New hose valves were provided where needed, and 242 feet of additional water pipe was laid in the nursery grounds, and two standpipes with hose valves placed thereon. Leaks in the main pipe line supplying the Capitol building with spring water were repaired, and a 2-inch street connection, and a three-quarter-inch pipe connection from this main to a hydrant at North Capitol and C streets were cut off, which has secured a better pressure at the Capitol. Eight hundred and seventy-five feet of new rubber hose was purchased to replace old hose no longer serviceable.

Necessary attention was paid to the fountains, the drainpipes from several that had become choked with tree roots having been taken up, cleaned, and relaid; jets were repaired, new ones placed on the fountains in Stanton Square, and the drain from east fountain taken up, cleaned, and relaid; a new cement bottom was placed in basin of fountain at New York avenue, between Tenth and Eleventh streets NW., a new standpipe and overflow put in, and new drain connection

made; the drains from fountain at Ninth street and Pennsylvania avenue NW., two in Lincoln Square, one in Sherman Square, and one at Third street and New York avenue NW., were taken up, cleaned, and relaid. The basins in fountains north, east, and south of the Executive Mansion, in Rawlins Square, at New York avenue, Third and M streets NW., and Twentieth and P streets NW., were repaired and new valves placed upon the water pipes supplying the following fountains: Folger Park, east of the Executive Mansion, Pennsylvania avenue and Ninth street NW., New York avenue, Third and M streets NW., Twentieth and P streets NW., New York avenue and Tenth street NW., and Pennsylvania avenue and Thirteenth street NW. A new overflow was placed in fountain in Sherman Park, the drinking fountains in various parks repainted, and minor repairs made to them as required. Work was commenced upon the construction of a fountain basin in the nursery grounds; it will be 43 feet long, 10 feet wide, and 3½ feet deep, and will be used for the propagation and growth of hardy flowering aquatic plants. The concrete foundation for this fountain basin has been laid, and water and drain pipes for its service put in and connected, leaving the remainder of the work to be completed after July 1.

The gas lamps in the public grounds were maintained in good condition during the year, broken glass in the lanterns being replaced with new, as required. The average number of burners lighted nightly during the year was 312.

EXECUTIVE MANSION, GREENHOUSES AND GROUNDS.

In the mansion new floors of encaustic tiles were laid in the two kitchens, the lower portions of the walls were wainscoted with similar materials, the woodwork repaired and repainted, and the ceilings and upper portions of walls recalcimined; the woodwork in basement corridor and laundry was repainted; the side walls and ceilings of basement corridor and hall, the laundry and small engine room were scraped, pointed up, and recalcimined; the walls of three office rooms were repapered, the cornices tinted, the woodwork in two of them touched up and varnished, and a new wood mantel with tiled hearth placed in one of the rooms; in three bedchambers the walls and ceilings were repapered, the cornices tinted, and the woodwork repainted; in one the walls and ceiling were repapered and the cornice tinted, and in another the window and bed cornices were regilded. The private dining room was repapered, the cornice tinted, and the woodwork repainted; in the small waiting room adjoining the entrance vestibule the walls and ceiling were repapered, the center piece on latter tinted, the woodwork touched up and varnished, and the mirror frame and window cornice regilded; one room in basement has been repapered, and the woodwork in that room, the butler's pantry, and the pipes in elevator shaft, have been repainted; in the corridor on second floor and the west end of lower corridor the walls have been repainted and decorated, the ceilings repapered, the cornices tinted, and the woodwork touched up and varnished; the partition formerly dividing the east end of corridor on second floor was removed, the side walls of the apartment repainted and redecorated, the ceiling repapered, and the woodwork revarnished. The ornamental partition formerly dividing the middle corridor on second floor was taken down and removed, three crystal gas brackets, removed from private dining room, placed on walls, and three chandeliers in this corridor were lowered. A portrait of Ex-President Cleveland, with suitable

frame, was purchased and hung in the mansion. Extensive improvements were made in the Blue Parlor; the walls and ceiling have been redecorated, the woodwork repainted, the furniture reupholstered and its frames regilded, a new carpet purchased, and new lace and drapery curtains provided for the windows. The chandeliers and gas fixtures in the mansion were overhauled, cleaned, repairs to them and to the plumbing arrangements made, and the plumbing in one of the closets improved; two storage closets were fitted up in the upper corridor, a china closet constructed in the butler's pantry, a new hand rail put up on one of the stairways, new sash locks and chains placed on the windows, and minor carpentry repairs made as required. For the purpose of furnishing the mansion with a supply of rain water, the 10-inch pipe connecting with copper leaders from roof was extended 220 feet under floor of basement corridor and connected with the large storage reservoir on east front, and from this reservoir a 2-inch suction pipe was run and connected with the pumping engine used to fill supply tank in garret. The exterior of the mansion, its tin-roof covering, and the iron railing east and west of north portico have been repainted; new drapery window curtains, and new door portieres were procured for the east room, and new carpet and matting purchased for other rooms. In the autumn all carpets were relaid and curtains were rehung, and in the spring the carpets were removed from the floors, the curtains taken down, and the rooms arranged for the summer; a set of awning blinds were placed at windows at west end of upper corridor, repairs made to the furniture in the mansion as needed, and some new articles for house furnishing purchased. Wires have been run and instruments placed in position for a telephonic connection with the third precinct police station, a watchman's time detector put in place near the main entrance and connected with nine stations in and about the mansion, and an electric-bell connection made with the watchman's lodge southeast of the building. A new water filter of large size was purchased, placed in position in the basement, and connected with the distributing pipes and with the main that supplies the house with Potomac water. Some minor repairs were made to the tin-roof covering and to the copper leaders, a new flag pole was erected upon the building, and a tile floor laid upon the south portico.

Wires and fixtures for providing the mansion with electric lights have been introduced during the year. The building has been wired and chandeliers and fixtures placed in position. All of the work contemplated for this improvement had not been placed in position at the close of the fiscal year, but it is expected to complete it after July 1, the unexpended balance of the appropriation provided for the purpose having been made available for use after that date. The work required to complete the system will be, in general, the placing of glass upon the fixtures in nine rooms and one corridor and hanging chandeliers in two rooms on second floor; on the first floor the fixtures are to be placed in the state dining room and butler's pantry, an additional fixture is to be placed in the red parlor, new switches are to go upon the east room circuit, switches are to be provided for the conservatory and the lower part of conservatory and camelia house are to be wired and provided with lamps, and fixtures are to be made for the outside canopies used on occasions of official receptions. The building is provided with the electric current through cables connected with the dynamo in the State, War, and Navy Department Building. The installation of the electric lights has been under the direct supervision of Passed Assistant Engineer G. W. Baird, U. S. Navy, to whose zeal and skill the success of this difficult work is due.

In the stable of the mansion repairs were made to the window frames, doors, stalls, and to one of the stairways, and a new trap door was constructed in floor of corridor. Repairs were also made to the exterior cornices and facia boards, some of the window blinds were repaired and rehinged, 720 linear feet of new tin gutter and spouting placed in position, and ten window sills covered with tin. All of the woodwork on the exterior, the ventilator and cupola on roof, and portions of the woodwork in the interior of stable and carriage houses were repainted.

Necessary repairs were made to the woodwork of the greenhouses and all broken glass was replaced with new; the exterior of the conservatory, rose, and camelia houses, interior and exterior of orchid house, exterior of geranium house, interior of grapery, and roof of propagating house were repainted; the flues, pipes, and chimneys of seven furnaces were cleaned and repaired; the magnesia sectional covering on some of the boilers was repaired and renewed, and a new floor of artificial stone laid in the flower room under the conservatory; 135 square yards of asphalt pavement and 164 linear feet of flagstone footwalk were laid upon the roadway which separates the conservatory and camelia house from the greenhouses on the west side of those buildings, and an asphalt footwalk covering an area of 40 square yards was laid between two of the greenhouses. Necessary attention was bestowed upon the large collection of plants, and desirable varieties for decorating the grounds were propagated; 15,575 bulbs of different varieties were purchased for winter forcing and for planting the flower beds for early spring bloom.

The grounds were maintained in good order during the year, necessary attention paid to the lawns, walks, and gutters, and a number of young trees and shrubs planted. In the autumn the flower beds were planted with hyacinths, tulips, and crocus, nearly 33,000 bulbs being used for the purpose; in the spring these were removed and replaced with about 30,000 summer decorative plants.

TELEGRAPH TO CONNECT THE CAPITOL WITH THE DEPARTMENTS AND GOVERNMENT PRINTING OFFICE.

The entire line was overhauled during the year, all slack in the wires pulled up and cut out, new cross arms and insulators put up where required, and brace wires placed on poles where needed. One mile of old and unserviceable wire was removed and replaced with new galvanized line wire. One new 40-foot pole was erected at Second and H streets NW., to replace one that was old and decayed. The fixtures on the Patent and Post Office Departments were repaired, and repairs were made to the underground cable on B street, between Sixth and Seventh streets NW., where it had been cut by workmen employed upon street improvements. The trees on Fourteenth street, between B street N. and B street S., were trimmed where their branches interfered with the wires. The main battery in this office and the local batteries in the several Departments were maintained in effective working order. Breaks in the line caused by storms were repaired and crosses and obstructions were removed from the wires as soon as possible after being located. The cables running through the basement of the Capitol were examined and refastened to the walls where required, and the instruments that had been removed from the tables of the operators in the Senate and House of Representatives and stored in this office during the recess were replaced and reconnected prior to the reassembling of Con-

gress. The offices in the Department of Agriculture and the Second Auditor's Office of the Treasury Department were moved into other rooms, the necessary changes made in the wires, and the instruments replaced and reconnected. The location of the table of the operator in the Government Printing Office was changed and the wires reconnected and a new switch and sounder placed on the table of the operator in the Post-Office Department. The wires on Fifteenth street, south of Pennsylvania avenue, were removed from two old poles and placed on new poles in the vicinity. Changes were made in the line of wires at Fifteenth street and Ohio avenue to get them out of the way of a building in course of erection at that point. Some old and unserviceable wire on the roof of the Department of Justice was removed and replaced with new wire, and the office of the Board of Management of Exhibits of the Government of the United States for the World's Columbian Exposition was, at the request of its secretary, connected with the line, the necessary material being furnished by the Board.

Attention is again respectfully invited to the fact that it is becoming more and more difficult to operate the overhead telegraph system, owing to the fact that the trees along the line are gradually growing up into the wires and interrupting the continuity of the electric currents, particularly during wet and windy weather. Not only have the present poles become too short, but many of them are rotting at the butts and are in constant danger of breaking from their own weight or of being blown down during storms. The necessity for either replacing the overhead wires with underground cables, or of replacing the present poles with taller ones, is obvious. An estimate for placing them under ground is herewith submitted. An alternative estimate for placing them overhead is also submitted.

SURVEYING AND DRAFTING.

The draftsman of public buildings and grounds is also custodian of the old records of the city of Washington in charge of this office and his time is mainly taken up with their care. He is required to exhibit them to owners of city property, to lawyers and real estate agents, and to produce them frequently in court. For more than three-quarters of the past fiscal year he has been engaged in searching these old records with the assistant district attorney, and by request of the latter, for evidence relating to the case of The United States *vs.* Morrison *et al.*, known as "the Potomac Flats case," and appearing as a witness in that case. He has also partially prepared plats showing reservations numbered 31, 82, 82½, 83, 84, 84½, 129½, 207, 208, 269, and 270, and additional improvements in the monument grounds.

In order that the draftsman may devote his whole time to surveying the public grounds and making the plans of them that are required by law to be kept in this office, a clerk should be provided to take charge of the old records, and the estimate submitted last year for that purpose is again presented and recommended.

Attention is again invited to the fact that there is reason to believe that a large number of lots in this city, to which the United States has a clear title, are held and occupied by private persons. It is of much importance that this office should be provided with the clerical force necessary to investigate this subject.

Estimates for the fiscal year ending June 30, 1893.

Salaries of employés, public buildings and grounds, etc.:		
One office clerk	$1,600	
One messenger	840	
One public gardener	2,000	
One clerk in charge of old public records of Washington City	1,500	
One clerk	1,400	
One electrician and telegraph lineman	1,000	
Overseers, foremen, draftsmen, gardeners, mechanics, and laborers	30,000	
One captain of the watch	1,200	
One day watchman at Lafayette Square	660	
One day watchman at Franklin Square	660	
Two day watchmen in Smithsonian Grounds, at $660 each	1,320	
Two night watchmen in Smithsonian Grounds, at $720 each	1,440	
One day watchman at Judiciary Square	660	
One night watchman at Judiciary Square	720	
One day watchman at Lincoln Square and adjacent reservations	660	
One day watchman at Iowa Circle	660	
One day watchman at Thomas Circle and neighboring reservations	660	
One day watchman at Washington Circle and Rawlins Square	660	
One day watchman at Du Pont Circle and neighboring reservations	660	
One day watchman at McPherson and Farragut squares	660	
One day watchman at Stanton Square and neighboring reservations	660	
Two day watchmen at Henry (Armory) and Seaton squares, at $660 each	1,320	
One night watchman at Henry (Armory) and Seaton squares	720	
One day watchman at Mt. Vernon Square and adjacent reservations	660	
One day watchman at grounds south of the Executive Mansion	660	
One watchman for greenhouses and nursery	660	
One day watchman for Marion Square, Folger Square, and adjacent reservations	660	
One day watchman at Garfield Park	660	
One night watchman at Garfield Park	720	
Contingent and incidental expenses	500	
		$56,180
Improvement and care of public grounds:		
Improvement and maintenance of grounds attached to the Executive Mansion; ordinary care of greenhouses and nursery; ordinary care of Lafayette and Franklin squares; construction and repair of post-and-chain fences, repair of high iron fences, and constructing stone coping about reservations; manure and hauling same; painting watchmen's lodges, iron fences, vases, lamps, and lamp-posts; purchase and repair of seats; purchase and repair of tools; trees, tree and plant stakes, labels, lime, whitewashing, and stock for nursery; removing snow and ice; flower-pots, twine, baskets, wire, splints, moss, and lycopodium; care, construction, and repair of fountains; abating nuisances; improvement, care, and maintenance of various reservations; improvement, care, and maintenance of Smithsonian Grounds and Judiciary Square	61,700	
Granite curbing about Franklin Square	5,000	
Care and improvement of Monument Grounds	10,000	
Continuing improvement of reservation No. 17, and site of old canal northwest of same	5,000	
Laying asphalt walks in various reservations	5,000	
Improvement and care of Henry and Seaton parks	5,000	
Lodges for park watchmen in Stanton, Mount Vernon, Iowa, Du Pont, Thomas, McPherson, and Folger reservations, at $500 each	3,500	

Improvement and care of public grounds:		
Constructing an ornamental fountain in Lafayette Square upon the site originally selected for the Lafayette statue ..	$4,000	
Replacing the old flagging pavement of the sidewalks in the grounds north of the Executive Mansion by a granolithic pavement........	2,500	
Construction of a large greenhouse at the propagating gardens for palms and tropical plants of large growth, needed for tropical bedding, etc., in the public parks during the summer months........	6,000	
Improvement of Howard University Park (reservation No. 246)	5,000	
		$112,700
Care of, repairs, fuel, etc., Executive Mansion:		
Care, repair, and refurnishing the Executive Mansion, to be expended by contract or otherwise, as the President may determine	25.000	
Fuel for Executive Mansion, greenhouses, and stable........	3,000	
Care and necessary repair of greenhouses........	5,000	
Renewing the superstructures of two greenhouses connected with the Executive Mansion	3,000	
		36,000
Lighting the Executive Mansion and the public grounds:		
Gas, pay of lamplighters, gas-fitters and laborers, purchase, erection, and repair of lamps and lamp posts, purchase of matches, and repairs of all kinds; fuel and lights for office and office stable, for watchmen's lodges, and for greenhouses at the nursery: *Provided*, That for each 6-foot burner not connected with a meter in the lamps on the public grounds no more than $21.50 shall be paid per lamp for gas, including lighting, cleaning, and keeping the lamps in repair, under any expenditure provided for in this act; and said lamps shall burn not less than 3,000 hours per annum; and authority is hereby given to substitute other illuminating material for the same or less price, and to use so much of the sum hereby appropriated as may be necessary for that purpose........	15,000	
Electric lights for 365 nights, from 7 posts, at 40 cents per light per night. $2.80 per night	1,022	
Erecting 8 iron posts in the Monument Grounds, connecting them with underground wires for electric lights, and supplying electric lights for the same........	2,000	
		18,022
Repairs to water-pipes and fire plugs:		
Repairing and extending water pipes, purchase of apparatus for cleaning them, purchase of hose, and for cleaning the springs and repairing and renewing the pipes of the same that supply the Capitol, the Executive Mansion and the building for the State, War, and Navy Departments.......		5,000
Telegraph to connect the Capitol with the Departments and Government Printing Office:		
Replacing the present system of wires with duplicate 6-conductor underground cable, being a total distance of about 6,625 linear feet........	31,000	
(An alternative estimate amounting to $1,600 is also submitted for replacing the present poles, with new and taller poles, and if an appropriation for that purpose be made it should be accompanied by authority to erect the poles.)		
Care and repair of existing lines........	1,500	
		32,500
Total		260,402

Washington Monument, elevator, electric lights, and machinery connected therewith. The following estimate for operating the elevator, the electric lights and machinery connected therewith, for the fiscal year ending June 30, 1893, is submitted:

One custodian, at $100 per month	$1,200
One steam engineer, at $90 per month	1,080
One assistant steam engineer, at $70 per month	840
One fireman, at $60 per month	720
One assistant fireman, at $60 per month	720
One conductor of elevator car, at $75 per month	900
One attendant on floor, at $60 per month	720
One attendant on top floor, at $60 per month	720
Three night and day watchmen, at $60 per month each	2,160
Fuel, lights, oil, waste, packing, tools, matches, paints, brushes, brooms, lanterns, rope, nails, screws, lead, electric lights, heating apparatus, oil stoves for elevator car and upper and lower floors, repairs to engines, boilers, dynamo, elevator, and repairs of all kinds connected with the monument and machinery, and purchase of all necessary articles for keeping the monument, machinery, elevator, and electric-light plant in good order	3,600
	12,660

As some of the foregoing estimates are larger than the amounts heretofore appropriated, and as others are for new work, it is deemed advisable to submit the following brief explanation in reference thereto:

First.—One public gardener, $2,000. I have asked for an increase in the salary of the public gardener, a position now so satisfactorily filled by Mr. George H. Brown. The duties of the office require that the gentleman who fills it shall be thoroughly skilled in the culture of trees, shrubs, and plants, and shall have a practical knowledge of civil engineering as applied to landscape gardening. Mr. Brown combines these attributes, to which he adds taste, industry, and integrity. His duties take him from one end of the city to the other. He is directly responsible for the care of the valuable collection of plants in the propagating garden, and superintends the propagation of plants that are annually raised for the public grounds, which this year numbered about 402,000.

Second.—One clerk in charge of old public records of Washington City, $1,500. These records include maps, deeds, record books, letters, etc., from the organization of the original board of commissioners, near the close of the last century, up to 1867, when the duties were turned over to the Chief of Engineers. They are constantly examined by attorneys and others interested in lands in Washington, and the person in charge of them is frequently required to produce them in courts; to index them properly, to be able to turn at once to the details of any question raised, requires familiarity with every paper. This work has for the last few years been intrusted to the only draftsman allowed this office, and during the past year more than three-fourths of his time has been actually employed on this duty. It is desirable that this appropriation be made in order that the draftsman may be permitted to attend to the necessary and legitimate duties of his office.

Third.—One clerk, $1,400. Of late years the office work has increased to such an extent that to properly perform it has required continuous work at night and on Sundays and holidays. This is a hardship, and as a remedy an appropriation for an additional clerk is recommended.

Fourth.—For one telegraph lineman, $1,000. The telegraph system under charge of this office includes about 8 miles of overhead wire and 2.6 miles of underground cable. There are twenty-one offices connected

with these lines, the main battery being at this office. The lineman is constantly engaged in the care of the main and local batteries and such necessary repairs and extensions as a system of wires of this kind requires. He is industrious, efficient, and capable, and has won the confidence of all with whom he has come in contact by faithful attention to his duties.

Fifth.—An estimate for a captain of the watch is submitted and recommended. Such an officer is much needed in order that the park watchmen may be under proper supervision.

Sixth.—Estimates for a day watchman for Marion and Folger squares and adjacent reservations, and for a day watchman for Garfield Park, are submitted and recommended. Marion and Folger squares contain an aggregate area of about 3 acres, and Garfield Park contains an area of about 24 acres. They are highly improved, and the necessity for providing watchmen for their care is apparent.

Seventh.—It will be observed that the estimate for "improvement and care of public grounds" is submitted in a smaller number of separate items than heretofore. A large number of items, being for such purposes as are required regularly every year, are lumped together in a single item; the several items, however, being enumerated, and it is recommended that the appropriation be made in that way instead of designating a specific sum for each of these small objects. Great labor in keeping the accounts would be saved, and the full amount of the appropriation be made available if a lump sum could be appropriated. It is not always practicable to spend an exactly even number of dollars for a particular purpose. When a specific amount is stated for each object it must not be exceeded, and the result is that some remnants of those small items can not be used at all. The method of appropriating a lump sum, as here suggested, seems to be in accordance with the practice of Congress in other cases, as, for example for the regular supplies and incidental expenses of the Quartermaster's Department, pages 149, 150, and 151 digest of appropriations 1892.

The aggregate amount requested for the consolidated items exceeds, in the sum of $10,250, the appropriation made for similar purposes for the fiscal year 1891–'92. The excess arises as follows, viz, $1,000 is asked for painting watchmen's lodges, iron fences, etc., instead of $750 last appropriated; $20,000 is asked for improvement, care, and maintenance of various reservations, in place of the $12,000 granted this year, and $7,000 is asked for improvement, care, and maintenance of Judiciary Square, in place of $5,000 last granted. It is proposed to improve as many as possible of the 200 unimproved reservations; each year from 1 to 5 are added to the list of improved reservations, and if the funds now requested become available, 8 or 10 can be added during the fiscal year ending June 30, 1893. As reservations are thus improved the expense of the care of the whole is slightly increased, for the improvements must be maintained.

Eighth.—For placing granite curbing about Franklin Square, $5,000 is asked. The beauty of this handsome park will be greatly enhanced by placing around it a granite curbing similar to those used around parks of the same style in the larger cities elsewhere.

Ninth.—For the care and improvement of the Monument Grounds, $10,000. It is desirable that this important improvement should progress more rapidly than heretofore.

Tenth.—For laying asphalt walks in various reservations, $5,000. It is proposed to replace with first-class asphalt walks the gravel paths in Washington Circle, Mount Vernon Square, Executive Mansion grounds

(south side), Lincoln Square, Stanton Square, Folger Square, Marion Square, Henry and Seaton parks, and to renew those in Farragut Square. In the late fall, winter, and early spring these walks are muddy and pedestrians seek the lawns, which are thus destroyed by trespassers. The amount of these paths which it is proposed to lay this year is about 3,500 square yards. Each autumn it becomes necessary to put down plank walks which must again be removed in the spring. If asphalt walks are laid the annual expense incident to plank walks will be avoided.

Eleventh.—For improvement, care, and maintenance of Henry (Armory) and Seaton Parks, $5,000. These reservations, extending from Seventh street to the Botanic Gardens, cover an area of 34 acres, with road and walk surfaces of over 10,000 square yards. They are in an advanced state of improvement. Their beauty has been marred by the depot and tracks of the Baltimore and Potomac Railroad. A mound has been constructed around the depot upon which it is intended to plant trees and shrubs, so that in time the depot will be hidden partially from view. The materials for this mound have thus far been obtained free of expense to the United States, and it is now proposed to grade the mound and to seed and plant it. The funds requested are needed for this purpose, and for the care of roads, lawns, gutters, etc., and laying out additional paths.

Twelfth.—For lodges for park watchmen in Stanton, Mount Vernon, Iowa, Du Pont, Thomas, McPherson, and Folger reservations, at $500 each, $3,500. The watchmen in these reservations are exposed to the inclemency of the weather at all seasons of the year. Ordinary humanity seems to call for this appropriation.

Thirteenth.—For constructing an ornamental fountain in Lafayette Square, upon the site originally selected for the Lafayette statue, $4,000. This space is on the Pennsylvania avenue side of the square, directly opposite the Executive Mansion. The old foundation made for the pedestal of the statue can not be removed without considerable expense, but can be utilized for the foundation of a basin for an ornamental fountain, for the erection of which this estimate is submitted.

Fourteenth.—For replacing the old flagging pavement of the sidewalks in the grounds north of the Executive Mansion by a granolithic pavement, $2,500. These sidewalks lead from the entrance gates on Pennsylvania avenue to the north front of the Executive Mansion. The old flagging at present composing them is in bad condition and should be replaced by a granolithic pavement.

Fifteenth.—An estimate amounting to $6,000 is also submitted for constructing a large greenhouse at the propagating gardens, for palms and subtropical plants. The greenhouse structures now existing at the gardens are of small size, and not of sufficient capacity to accommodate that class of plants.

Sixteenth.—An estimate amounting to $5,000 is submitted for improving reservation No. 246, known as Howard University Park. This park contains an area of about 11½ acres, and is unimproved.

Seventeenth.—For renewing the superstructures of two greenhouses connected with the Executive Mansion, $3,000. These structures are old and in bad condition and must be renewed to preserve the plants which they contain.

Eighteenth.—The estimate for the item for "gas, pay of lamplighters, etc.," under the title "Lighting the Executive Mansion and the public grounds," has been increased from $14,000 to $15,000. In the appro-

priation act for the fiscal year ending June 30, 1892, the amount to be paid per annum for lighting, etc., each gas lamp in the public grounds was increased from $20 to $21.50, and to provide for this increase, and for the additional amount that it is estimated will be required for the care and maintenance of the electric lamps and wires recently introduced into the Executive Mansion, the additional $1,000 is asked.

Nineteenth.—An estimate of $2,000 is submitted for erecting eight iron posts in the Monument Grounds, connecting them with underground wires for electric lights, and supplying electric lights for the same. Since the introduction of electric lights in the grounds south of the Executive Mansion the travel after nightfall through that park has increased. Much of this travel passes through the Monument Grounds, which are not now provided with any system of illumination.

Twentieth.—The estimate for repairs to water pipes and fire plugs has been increased from $2,500 to $5,000. The sources of the spring which supplies the United States Capitol with water were much impaired by the excavations made in connection with the construction of the large reservoir near the Howard University for the increase of the city's supply of Potomac water, which has resulted in diminishing the pressure at the Capitol. It is proposed to use the additional amount requested in making connection with the strongest springs in the cinity and in overhauling and repairing the old pipe line, and renewing such portions of it as may be found unserviceable.

Twenty-first.—An estimate is again submitted for replacing the overhead wires between the Capitol and the Departments with a duplicate underground six-wire cable. The growth of the trees on the sidewalks renders it absolutely necessary, in order to maintain telegraphic communication over these wires, either to erect at once taller poles, at a cost of about $1,600, or to lay an underground cable, at a cost of $31,000. It appears to be the will of Congress that no more overhead wires shall be placed in this city (see District of Columbia appropriation, act of July 18, 1888), otherwise I should recommend the appropriation of the smaller amount.

Twenty-second.—I recommend that the salaries of the two steam engineers at the Washington Monument be increased from $80 and $60 to $90 and $70 per month, respectively. The duties of these two men are of great importance; upon their efficiency and intelligence depend, to a great extent, the lives of those who use the elevator; the increase asked is small and the men deserve it. I also recommend that the pay of the two firemen be placed at $60 per month each. That is the rate allowed firemen in the Executive Departments, and there appears to be no reason why the firemen at the monument should receive less.

The item for fuel, lights, oil, waste, repairs, etc., should be increased from $3,000 to $3,600 for the purpose of painting the ironwork in the interior of the monument.

Financial statement for fiscal year ending June 30, 1891.

Title of appropriation.	Available at beginning of fiscal year.	Appropriated by deficiency act approved Mar. 3, 1891.	Expended during fiscal year.	Unexpended balance to revert to the Treasury.
Improvement and care of public grounds	$66,450	....	$65,986.11	$463.89
Repairs, fuel, etc., Executive Mansion	33,000	....	32,972.68	7.32
Lighting, etc., Executive Mansion, etc	22,722	*$5,750	26,299.03	96.97
Repairs to water pipes and fire plugs	2,500	....	2,433.42	66.58
Telegraph to connect the Capitol with the Departments and Government Printing Office	1,250	....	1,248.98	1.02
Contingent expenses public buildings and grounds under Chief Engineer	500	....	499.20	.80
Salaries of employés public buildings and grounds under Chief Engineer	47,620	....	47,572.99	47.01
Care and maintenance of the Washington Monument	11,120	....	11,119.56	.44
Portrait of Grover Cleveland, ex-President of the United States (act August 30, 1890)	2,500	....	2,500.00	....

* Of this amount $2,076 has been made a "no limit" appropriation, available after June 30, 1891.

I am, general, very respectfully, your obedient servant,

O. H. ERNST,
Colonel, U. S. A., Major Corps of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

APPENDIX F F F.

SURVEY OF THE NORTHERN AND NORTHWESTERN LAKES.

F F F 1.

RESURVEY OF MARQUETTE HARBOR.

REPORT OF CAPT. WALTER L. FISK, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

(For letter of transmittal, see Appendix K K.)

This is merely a partial survey for the purpose of correcting the U. S. Lake Survey chart of Marquette Harbor to date. It was ordered by the Chief of Engineers in a letter dated December 9, 1890, and an allotment of $200 was made for it from the appropriation for Survey of Northern and Northwestern Lakes.

The field work was done in January and March of this year, and as soon as other work will permit the map will be corrected and forwarded.

F F F 2.

ISSUE OF PUBLISHED CHARTS OF THE NORTHERN AND NORTHWESTERN LAKES.

REPORT OF COLONEL O. M. POE, CORPS OF ENGINEERS, BVT. BRIG. GEN., U. S. A., FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

UNITED STATES ENGINEER OFFICE,
Detroit, Mich., July 1, 1891.

SIR: I have the honor to transmit herewith, in duplicate, my annual report on the "issue of the published charts of the Northern and Northwestern Lakes" for the fiscal year ending June 30, 1891. * * *

Very respectfully, your obedient servaant,

O. M. POE,
Colonel, Corps of Engineers,
Bvt. Brig. Gen., U. S. A.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

ISSUE OF THE PUBLISHED CHARTS OF THE NORTHERN AND NORTHWESTERN LAKES.

Until July 16, 1890, charts were sold at the uniform price of 30 cents each. On that date, however, a decision of the Secretary of War was received by which, under date of June 28, 1890, it was directed that the future price per chart should be 20 cents, as it was found that that sum amply covered the cost of paper and printing, which determines the authorized charge according to the acts of May 4, 1878, and February 14, 1879.

Since the receipt of this decision nearly all charts have been sold at the uniform price of 20 cents each. A few special lithograph charts have been sold for 10 cents, and some charts have been issued free of charge for the official use of Government agents applying for them.

The following table shows the extent of this business:

Issue of the charts of the Northern and Northwestern lakes during the fiscal year ending June 30, 1891.

Description.	Number.	Total.
On hand July 1, 1890	6,202	
Received during year	8,110	
		14,312
Issued to United States vessels and officials	500	
Sold at 30 cents each	599	
Sold at 20 cents each	5,339	
Sold at 10 cents each	39	
		6,477
On hand July 1, 1891		7,835

The sum of $1,251.40 was turned into the Treasury from sales of charts.

Total number of charts issued to July 1, 1890	174,709
Issued between July 1, 1890, and July 1, 1891	6,477
Total issued to July 1, 1891	181,186

Under the appropriation of $2,000 made by act of Congress, approved August 30, 1890, "for printing and issuing charts for use of navigators and electrotyping plates for chart-printing," an allotment of $500 was made on March 14, 1891, to be applied to incidental expenses connected with issuing Lake Survey charts. Of this sum $83.20 was expended for stationery under informal contract with the Richmond & Backus Co., dated March 7, 1891; and the balance of the $500 was expended for pay of office force, etc.

It is now just 11 years since the last of the topographical work of the United States Lake Survey was done, and many of the charts now issued are based upon surveys made 30 and 35 years ago, notably the two charts of St. Marys River, the surveys for which were made between 1853 and 1857. Many new towns of considerable importance are not shown on the charts, and a complete set of coast charts on a $\frac{1}{80000}$ scale has never been made for Lakes Huron and Superior. The commerce of the latter has increased from the small volume of 1855 to over 9,000,000 tons in 1890, while an annual tonnage of over 20,000 now passes through Lake Huron. Moreover, with the improvement of channels the draft of vessels has increased, first from 9½ to 12 feet, and then from 12 to 16 feet. Improvements now in progress will before many years secure

a draft of 20 feet, and every season the larger vessels are discovering dangers previously unknown.

An effort is made to plot upon existing charts the various newly discovered dangers, the various lights established from time to time by the Light-House Department, and the various river and harbor improvements, but it is a matter of great difficulty to keep up to date all the charts for these thousands of miles of coast, and many of the charts now require additions and corrections to render them of the greatest service, and in some cases new surveys are required to obtain the necessary information.

The Lake Survey records in charge of the Corps of Engineers are available, and will save the duplication of much of the work. Many of the instruments used on the Lake Survey are also in charge of the Corps of Engineers, and are likewise available. In addition much information can be obtained, at little cost, from the offices of the various engineer officers who are in charge of works of river and harbor improvement, and who are the engineers of the various light-house districts.

In view of the vast commercial importance of the lake marine, and of the benefit that would result from the issue of charts constantly revised up to date, I do not consider an annual appropriation of $50,000 too large for the purpose. The information obtained would also be of value for private enterprises of different kinds, and forming, as the Great Lakes do, the frontier of the country, much valuable military information could also be obtained.

The cost of printing and issuing charts is now so small that it can not be further reduced, and I therefore submit the following:

Estimate for the fiscal year ending June 30, 1893.

For printing and issuing charts for the use of navigators and electrotyping copper plates for chart-printing	$3,000
For surveys and other expenses connected with correcting and extending the charts of the northern and northwestern lakes	50,000
Total	53,000

Abstract of bids for furnishing stationery for survey of Northern and Northwestern Lakes, 1891, received and opened February 13, 1891, in accordance with advertisement dated January 24, 1891.

No.	Name and address of bidder.	Approximate total.
1	The Richmond & Backus Company, Detroit, Mich	*$83.20

* Recommended for acceptance.

APPENDIX G G G.

CONSTRUCTION AND IMPROVEMENT OF ROADS AND BRIDGES IN THE YELLOWSTONE NATIONAL PARK.

REPORT OF MAJOR WILLIAM A. JONES, CORPS OF ENGINEERS, OFFICER IN CHARGE, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

UNITED STATES ENGINEER OFFICE,
St. Paul, Minn., July 8, 1891.

GENERAL: I have the honor to transmit herewith my annual report, in duplicate, upon the improvement and construction of roads and bridges in the Yellowstone National Park, for the fiscal year ending June 30, 1891.

Very respectfully, your obedient servant,

W. A. JONES,
Major, Corps of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

The project for this work was adopted in 1883, when the control was placed in the hands of officers of the Corps of Engineers, and consists in the construction and maintenance of about 225 miles of road, with the necessary bridges, culverts, etc. The roads embraced in the project commenced at Gardner, at the north boundary line of the Park, thence to Mammoth Hot Springs; thence to Upper Geyser Basin, passing through Norris Geyser and Lower Geyser Basins; thence to the outlet of Yellowstone Lake via Shoshone Lake and the west arm of Yellowstone Lake, crossing the Continental Divide of the Rocky Mountains twice; thence to Yanceys via the Falls and Grand Cañon of the Yellowstone River; thence to Mammoth Hot Springs, completing the so-called belt road with a circuit of about 145 miles. In addition there are projected: A road from the west boundary line of the Park, passing through Lower Geyser Basin and continued easterly to intersect the road along the Yellowstone River to the Falls; a road from Norris Geyser Basin to the Falls of the Yellowstone; a road from Yanceys to the east boundary line of the Park; and a number of short branch roads and trails from the above-named roads to objects of interest off the main line of travel; in all, 225 miles of new roads, about 20 large and 50 small bridges, with many culverts, etc. Estimated cost, as revised in 1889 by my predecessor, $444,779.42.

The act of Congress approved March 3, 1891, changed the project of the part of the belt line between Lower Geyser Basin and Yellowstone Lake by requiring the road to be built "by the shortest practicable route" from Fountain Geyser to the thumb of the Yellowstone Lake. This change will not materially affect the cost.

At the beginning of the year the roads that were opened to travel were:

Completed roads.—(1) The road from Gardiner to Mammoth Hot Springs, Norris, Lower and Upper Geyser basins, completed, except a projected stretch of 8.9 miles of new road in Gibbon Cañon, designed to replace an equal length of the old road, and some minor changes in the location of different parts of the road. (2) The road from Norris Geyser Basin to the Falls of the Yellowstone.

Uncompleted roads.—(1) The road from Upper Geyser Basin to the Falls of the Yellowstone via Yellowstone Lake and outlet. (2) The two roads known as the Madison Cañon road and Howard trail, from the western boundary line of the Park to Lower Geyser Basin, where they joined, and their continuation as one road to the uncompleted road from Yellowstone Lake outlet to the Falls. (3) The road from Mammoth Hot Springs to Yanceys and its continuation to eastern boundary of the Park.

Total amount expended upon the project since commencement of work in 1883 to June 30, 1890, including outstanding liabilities, $184,779.42.

The appropriation of August 30, 1890, came too late to permit of any operations during the current year, and it was only through a desperate survey campaign in winter that there could be any hope of saving the appropriation from reversion to the Treasury on the 30th of June, 1891. Yellowstone Park is practically a high mountain region where winter snows set in early and stay late. The appropriations revert to the Treasury on the 30th of June of each year, and there is never more than a few weeks available for work in each season prior to that time. In this case a large portion of the work was required by the law to be done by contract. This necessitated a survey, to enable a specification of location and quantity and quality of work before advertising. It was out of the question to do this and go through the formalities of a contract in the short season of spring prior to June 30, 1891. The survey had to be made in the preceding fall. With all possible dispatch, after the appropriation reached my hands, I placed a survey party in the field under charge of Lieutenant Craighill in person, to whom great credit is due for accomplishing the work in the face of the hardships of winter. Attention is invited to his report herewith. This survey was carried across the Continental Divide of the Rocky Mountains in the midst of a great deal of snow and severe cold. It cost $2,700, the greater part of which could have been saved had we not been so sorely handicapped.

In the same hurried manner I placed a large repair party in the field, which in the few weeks of available time did a great deal of work, and placed the whole completed system of roads in most thorough repair. It was considered best to do the repair work for the season of 1891 in the preceding fall, so that the winter snows and spring rains could pack the work down and thus largely reduce the dust which results from placing traffic on fresh work after it has become dried out in early summer.

The outfit of supplies and men left Livingston, Mont., on the morning of October 2, 1890, and proceeded by rail to Cinnabar, Mont., where they were met by wagon transportation. With this they proceeded to

the field of operations, distant about 50 miles, taking tools, mess supplies and camp equipage at Mammoth Hot Springs. Two parties were sent in, each with a foreman, subforeman, cook, 37 teams, and 37 laborers. The latter were increased to 75 a few days later. One force commenced operations in the Geyser Basins, and the other in Gibbon Cañon.

The road in Gibbon Cañon which skirts the river band was extensively riprapped on the river slopes and considerable retaining wall was built. The corduroy and road at north end of this cañon were repaired and graded in a substantial manner. The large bowlders which impeded travel at Monument Geyser Basin were removed by blasting, and the road widened. The road at this point was narrow and in bad condition, the surface being a ledge of rock through the seams of which considerable water continually issued. The water was carried off by means of a culvert, and a layer of clay and gravel was spread over the rock.

The road between Upper and Lower Geyser Basins was constructed in 1885, since which time it has received no repairs. The whole distance was thoroughly and extensively repaired, covered with gravel in places, and bridges and culverts all made good.

The ford of Gibbon River near Cañon Creek had been badly washed out, and the approaches were very muddy. A very good temporary bridge was placed here.

The roads in the vicinity of Norris Geyser Basin, and from thence to the Grand Cañon, and also that in the vicinity of Swan Lake, were thoroughly repaired, a great deal of new covering in the shape of gravel and clay being placed, and all the culverts and bridges made good.

On the 31st of October the bulk of the repair party was discharged, having put extensive repairs on about 55 miles of road.

While this repair work was going on the survey party was floundering in the snows of the Continental Divide, and had reached the west end of Yellowstone Lake. By the 26th of November the survey was completed, having located and taken the necessary measurements for quantities on a line 64 miles long, mostly through timber and crossing the Continental Divide twice. This terminated the field work of the season of 1890.

During the winter the notes of survey were worked up and the necessary profiles, sections, and quantity estimates prepared. Proposals were thereafter invited for constructing 25 miles of road, and contracts were let on May 16, 1891, to Wyatt & Scott, of Gardiner, Mont., for 7½ miles, and to William Z. Partello, of Washington, D. C., for 20.3 miles. This work to be completed by October 1, 1891, and covers the stretch between the Grand Cañon and the west end of Yellowstone Lake.

In the mean time, on March 3, 1891, Congress made further appropriation of $75,000 for the year ending June 30, 1892, and at the same time reappropriated such balance of the appropriation for 1890-'91 as might remain on hand June 30, 1891. This method of continuing the appropriation worked very well in this case, but it will not answer for the long sessions of Congress, when the appropriation bills are not passed until after the 30th of June.

The following illustration of the operation of the law which requires these appropriations to revert to the Treasury on the last day of each fiscal year is presented to accentuate the suggestion that a proviso be attached to the appropriation clause relieving it from the reversion requirement of the general act to which it belongs. This act makes provision for certain current annual expenses, and it is an excellent provision that after these expenses have been met the balances should revert to the Treasury.

On the 30th of June, 1890, Congress was still in session, but had not acted on the sundry civil bill, which carries the appropriation for this work. Under the operation of the law, no funds could be carried beyond that date for the care and maintenance of the roads and the public property on hand. Consequently, on that date all employes had to be discharged, and the public property, for which I was personally responsible and the loss of any part of which had to be made good from my private resources, had to be left to the mercy of chance until I became officially aware of the appropriation, which was passed August 30, 1890. It should be observed that under the decisions of the proper officers of the Government, I could not contract with any persons for their services in the care of this property under these circumstances.

Early in the present season Lieutenant Craighill was sent into the field to make preparations for the extensive operations involved in spending two appropriations in one season. But shortly after his arrival he was relieved from duty with me, and Lieut. H. M. Chittenden, Corps of Engineers, was ordered to take his duties. This involved some delay, so that the main field operations did not get well under way before the middle of June. By this time Wyatt & Scott had begun work on their contract, and the slight repairs incident to the weather of the past winter had been completed. Also the two reconnoissances for locating the new road between the west end of Yellowstone Lake and the Fountain Geyser Basin had been made. The act of March 3, 1891, had changed the location between these points as set forth in our approved projects, and called for the shortest practicable line between these points. This required pretty lively work. since construction had to wait for it.

On the 22d of May, Mr. E. Lamartine, overseer, with three men and a pack outfit, started from Fountain Geyser Basin to explore for this route. He made a thorough examination of all the lofty country between the Geyser Basins, Shoshone Lake, Yellowstone Lake, and Nez Percé Creek. He found the country along the direct line between the terminals to be of the roughest description. There were no passes through the Continental Divide, and to flank it by passing around along its northern slopes involved crossing the heavy cañon cuttings of the Nez Percé Creek drainage. The parties who were anxious for a short line across this country not feeling satisfied with this, I went out in person to give them an opportunity to show me a good route, but by this time personal examination had satisfied them that such did not exist. At this time a possible line via Excelsior Geyser and Mallard Lake suggested itself, and I sent Mr. Lamartine out to examine it. After two days' exploration he returned, and all parties were satisfied that it was not practicable. A good line was selected which crosses the divide at Norris Pass and strikes the Geyser Basins at the head. It is all mountain work and all timbered. On the 16th of June two parties were sent in, one to operate at each end of the line. No difficulty was in the way of the one for the Geyser Basin end, but the one for the lake end had no means of approach and no line of communication had been established. Fortunately a steamboat was found in working order on the lake, and th party and outfit was placed by means of it. To furnish communicatio for this party and all of the contract parties along the river and lake a small steam launch, 40 feet long, was sent by rail to Cinnabar an thence hauled by wagon to the river, a distance of 60 miles. Two freigh cars were required to carry it by rail. The whole operation was rapidl and successfully executed.

The two working parties above referred to consisted each of two fore men, two cooks, sixteen teams, and forty laborers, with a complete outfi

for clearing and grading. The teams will be increased when the parties get strung out so that more can be used. About the time these parties became engaged the portable sawmill was moved from Mammoth Hot Springs to the Grand Cañon, a distance of 32 miles, and commenced work getting out timber for the culverts and bridges on the lake and river line. Also the whole line of finished road was divided into three sections, and permanent repair gangs placed upon each section. A gang was also sent out with the grader to operate on all three sections as needed. As soon as possible a road roller will be added, and with this outfit it is expected that the whole line will be maintained in excellent repair continuously at very much less cost than ever before.

I have concluded it to be possible to suppress the dust nuisance within the limits of reasonable expense, and had made preparations to begin this year, but Divine Providence has interfered by furnishing an extraordinary rainfall, so that we have had mud and not dust to deal with so far. I will, therefore, do nothing beyond getting ready for next season.

When the season opened this year our whole line of road was in superb condition, but the extensive building operations going on in the park developed a great traffic of heavy freight wagons, loaded ordinarily with about 3,000 pounds. In the midst of the strain thus produced on ordinary dirt roads an excessive and long-continued rainfall set in, and the roads in many places became very muddy. It is much to their credit that they did not become impassable. All traffic, however, has been continuously maintained, and with the experience gained as to the locality of our weak spots and the operation of the repair parties, I anticipate but little trouble in maintaining good roads in the future.

No reports as to work accomplished up to June 30 having come in, nothing can be stated thereof now.

It is proposed during the present working season to build the road from the Geyser Basin to Yellowstone Lake and thence along the lake shore and river to the Grand Cañon. in all about 50 miles in length, and possibly to build a part of the unfinished road betweed Gibbon Cañon and Lower Fire Hole Basin.

During the next season it is proposed to do as much work on the road between Grand Cañon, Yanceys, and Mammoth Hot Springs, as the sum that may be appropriated will accomplish. It is estimated that the sum of $150,000 can be profitably expended.

The estimates of "amount required for completion of existing project," which are annually submitted, only apply to the construction of new road. They do not cover current repairs and maintenance. These items will amount to $12,000 in the season of 1891, and will be proportionately increased with the addition of new road.

In conclusion I desire to acknowledge the assistance rendered by Lieut. W. E. Craighill, Corps of Engineers, and Lieut. H. M. Chittenden, Corps of Engineers, who have been in local charge of the work, and also of Mr. E. Lamartine, overseer.

Amount expended during the fiscal year ending June 30, 1891, including outstanding liabilities, $26,166.29.

ABSTRACT OF ALLOTMENTS AND APPROPRIATIONS.

Allotments.

Under the appropriation of 1883	$23,570.03
Under the appropriation of 1884	23,000.02
Under the appropriation of 1885	23,209.37

Appropriations.

By act approved August 4, 1886	$20,000.00
By act approved March 3, 1887	20,000.00
By act approved October 2, 1888	25,000.00
By act approved March 2, 1889	50,000.00
By act approved August 30, 1890	75,000.00
By act approved March 3, 1891	75,000.00
Total of allotments and appropriations	334,779.42

Money statement.

July 1, 1890, balance unexpended		$4,825.13
Amount appropriated by act approved August 30, 1890		75,000.00
Amount appropriated by act approved March 3, 1891		75,000.00
		154,825.13
June 30, 1891, amount expended during fiscal year		21,844.40
July 1, 1891, balance unexpended		132,980.73
July 1, 1891, outstanding liabilities	$9,148.02	
July 1, 1891, amount covered by uncompleted contracts	47,917.17	
		57,065.19
July 1, 1891, balance available		75,915.54
Amount (estimated) required for completion of existing project		197,000.00
Amount that can be profitably expended in fiscal year ending June 30, 1893		150,000.00

Abstract of proposals for building wagon roads in Yellowstone National Park, received in response to the advertisement dated March 25, 1891, and opened April 25, 1891, by Maj. W. A. Jones, Corps of Engineers, U. S. Army.

Description.	1. W. A. Campbell, Dodge Center, Minn.		2. Henry F. Balch, Minneapolis, Minn., and Horace E. Stevens, St. Paul, Minn.		3. Geo. Parker & Co., Hastings, Minn.	
	Price.	Amount.	Price.	Amount.	Price.	Amount.
Section 1:						
37,805 cubic yards earth excavation	$0.30	$11,341.50	$0.40	$15,122.00	$0.29	$10,963.45
Rock excavation	4.50		2.00		1.60	
Loose rock excavation	2.50		1.00		0.75	
Retaining wall	10.00		4.00		4.00	
500 cubic yards riprap	8.00	4,000.00	2.50	1,250.00	1.75	875.00
13.6 acres grubbing and clearing	200.00	2,720.00	75.00	1,020.00	115.00	1,564.00
		18,061.50		17,392.00		13,402.45
Section 2:						
27,770 cubic yards earth excavation	0.30	8,331.00	0.40	11,108.00	0.29	8,053.30
Rock excavation	4.50		2.00		1.60	
Loose rock excavation	2.50		1.00		0.75	
Retaining wall	10.00		4.00		4.00	
350 cubic yards riprap	8.00	2,800.00	2.50	875.00	1.75	612.50
17.2 acres grubbing and clearing	200.00	3,440.00	75.00	1,290.00	115.00	1,978.00
		14,571.00		13,273.00		10,643.80
Section 3:						
42,140 cubic yards earth excavation	0.30	12,642.00	0.40	16,856.00	0.29	12,220.60
Rock excavation	4.50		2.00		1.60	
Loose rock excavation	2.50		1.00		0.75	
Retaining wall	10.00		4.00		4.00	
Riprap	8.00		2.50		1.75	
16 acres grubbing and clearing	200.00	3,200.00	75.00	1,200.00	115.00	1,840.00
		15,842.00		18,056.00		14,060.60
Section 4:						
45,175 cubic yards earth excavation	0.35	15,811.25	0.40	18,070.00	0.29	13,100.75
200 cubic yards rock excavation	4.50	900.00	2.00	400.00	1.60	320.00
Loose rock excavation	2.50		1.00		0.75	
3,850 cubic yards retaining wall	10.00	38,500.00	4.00	15,400.00	4.00	15,400.00
100 cubic yards riprap	8.00	800.00	2.50	250.00	1.75	175.00
3 acres grubbing and clearing	200.00	600.00	75.00	225.00	115.00	345.00
		56,611.25		34,345.00		29,340.75

Abstract of proposals for building wagon roads in Yellowstone National Park, etc.—Cont'd.

Description.	1. W. A. Campbell, Dodge Center, Minn.		2. Henry F. Balch, Minneapolis, Minn., and Horace E. Stevens, St. Paul, Minn.		3. Geo. Parker & Co., Hastings, Minn.	
	Price.	Amount.	Price.	Amount.	Price.	Amount.
Section 5:						
10,590 cubic yards earth excavation	$0.30	$3,177.00	$0.40	$4,236.00	$0.29	$3,071.10
Rock excavation	4.50		2.00		1.60	
Loose rock excavation	2.50		1.00		0.75	
Retaining wall	10.00		4.00		4.00	
Riprap	8.00		2.50		1.75	
6.4 acres grubbing and clearing	200.00	1,280.00	75.00	480.00	115.00	736.00
		4,457.00		4,716.00		3,807.10
Aggregate		109,542.75		87,782.00		71,254.70

Description.	4. A. L. Love, Livingston, Mont.		5. Wm. J. Preston, St. Paul, Minn.		6. Smith & Bradbury, Kansas City, Mo.	
	Price.	Amount.	Price.	Amount.	Price.	Amount.
Section 1:						
37,806 cubic yards earth excavation	$0.28	$10,585.40	$0.29	$10,963.45	$0.65	$24,573.25
Rock excavation	1.49		2.50		2.00	
Loose rock excavation	0.53		1.00		1.00	
Retaining wall	4.57		5.00		5.00	
500 cubic yards riprap	1.97	985.00	2.25	1,125.00	3.50	1,750.00
13.6 acres grubbing and clearing	39.50	537.20	30.00	408.00	150.00	2,040.00
		12,107.60		12,496.45		28,363.25
Section 2:						
27,770 cubic yards earth excavation	0.28	7,775.60	0.29	8,053.30	0.65	18,050.50
Rock excavation	1.47		2.50		2.00	
Loose rock excavation	0.53		1.00		1.00	
Retaining wall	4.57		5.00		5.00	
350 cubic yards riprap	1.97	689.50	2.25	787.50	3.50	1,225.00
17.2 acres grubbing and clearing	39.50	679.40	30.00	516.00	150.00	2,580.00
		9,144.50		9,356.80		21,855.50
Section 3:						
42,140 cubic yards earth excavation	0.28	11,799.20	0.29	12,220.60	0.65	27,391.00
Rock excavation	1.47		2.50		2.00	
Loose rock excavation	0.57		1.00		1.00	
Retaining wall	4.53		5.00		5.00	
Riprap	1.97		2.25		3.50	
16 acres grubbing and clearing	39.25	628.00	30.00	480.00	150.00	2,400.00
		12,427.20		12,700.60		29,791.00
Section 4:						
45,175 cubic yards earth excavation	0.29	13,100.75	0.29	13,100.75	0.65	29,363.75
200 cubic yards rock excavation	1.49	298.00	2.50	500.00	2.00	400.00
Loose rock excavation	0.59		1.00		1.00	
3,850 cubic yards retaining wall	4.51	17,363.50	5.00	19,250.00	5.00	19,250.00
100 cubic yards riprap	1.98	198.00	2.25	225.00	3.50	350.00
3 acres grubbing and clearing	39.15	117.45	30.00	90.00	150.00	450.00
		31,077.70		33,165.75		49,813.75
Section 5:						
10,590 cubic yards earth excavation	0.27	2,859.30	0.29	3,071.10	0.65	6,883.50
Rock excavation	1.49		2.50		2.00	
Loose rock excavation	0.57		1.00		1.00	
Retaining wall	4.55		5.00		5.00	
Riprap	1.97		2.25		3.50	
6.4 acres grubbing and clearing	39.00	249.60	30.00	192.00	150.00	960.00
		3,108.90		3,263.10		7,843.50
Aggregate		67,865.90		70,982.70		137,667.00

Abstract of proposals for building wagon roads in Yellowstone National Park, etc.—Cont'd.

Description.	7. Sid. J. Truax and Geo. J. Hethering-ton, Hastings, Minn.		8. Wyatt & Scott, Gardiner, Mont.*		9. Wm. Z. Par-tello, Washing-ton, D. C.†	
	Price.	Amount.	Price.	Amount.	Price.	Amount.
Section 1:						
37,805 cubic yards earth excavation...	$0.28	$10,585.40			$0.22	$8,317.10
Rock excavation	1.00				3.75	
Loose rock excavation	2.00				1.05	
Retaining wall	5.00				6.00	
500 cubic yards riprap	2.00	1,000.00			2.00	1,000.00
13.6 acres grubbing and clearing	100.00	1,360.00			27.00	367.20
		12,945.40				9,684.30
Section 2:						
27,770 cubic yards earth excavation...	0.28	7,775.60			0.22	6,109.40
Rock excavation	1.00				3.75	
Loose rock excavation	1.50				1.05	
Retaining wall	3.00				6.00	
350 cubic yards riprap	2.00	700.00			2.00	700.00
17.2 acres grubbing and clearing	100.00	1,720.00			27.00	464.40
		10,195.60				7,273.80
Section 3:						
42,140 cubic yards earth excavation...	0.30	12,642.00			0.22	9,270.80
Rock excavation	1.00				3.75	
Loose rock excavation	1.50				1.05	
Retaining wall	4.00				6.00	
Riprap	1.00				2.00	
16 acres grubbing and clearing	100.00	1,600.00			27.00	432.00
		14,242.00				9,702.80
Section 4:						
45,175 cubic yards earth excavation...	0.32½	14,681.87	$0.25	$11,293.75	0.22	9,938.50
200 cubic yards rock excavation	1.50	300.00	2.00	400.00	3.75	750.00
Loose rock excavation	1.50		0.80		1.05	
3,580 cubic yards retaining wall	5.00	19,250.00	2.00	7,700.00	6.00	23,100.00
100 cubic yards riprap	1.00	100.00	2.00	200.00	2.00	200.00
3 acres grubbing and clearing	75.00	225.00	250.00	750.00	27.00	81.00
		34,556.87				34,069.50
Section 5:						
10,590 cubic yards earth excavation...	0.25	2,647.50			0.22	2,329.80
Rock excavation	1.00				3.75	
Loose rock excavation	1.50				1.05	
Retaining wall	5.00				6.00	
Riprap	3.00				2.00	
6.4 acres grubbing and clearing	75.00	480.00			27.00	172.80
		3,127.50				2,502.60
Aggregate		75,067.37		20,343.75		63,233.00

*Accepted. †Accepted for sections 1, 2, 3, and 5.

Abstract of proposals for building a dwelling-house, office and warehouse, and stable at Mammoth Hot Springs, Wyo., opened April 25, 1891, by Maj. W. A. Jones, Corps of Engineers.

No.	Name and address of bidder.	For the buildings comple
1	Donohue & Hoffman, St. Paul, Minn	*$12,000. / 10,850.
2	R. C. Thomas, Livingston, Mont	9,890.
3	William C. Douglass, Livingston, Mont	9,000.
4	Forster & Smith, Minneapolis, Minn	12,445.

All rejected.

* No plumbing. Will construct the buildings complete for $10,850 provided they are awarded t contract for buildings at Camp Sheridan.

Abstract of proposals for team hire opened May 30, 1891, by Maj. W. A. Jones, Corps of Engineers.

[Horse or mule teams, with drivers and equipment.]

No.	Name and address of bidder.	Teams.	Price per team per day of ten hours.
1	Geo. Parker & Co., Hartings, Minn	70	$8.90
2	W. A. Campbell, Dodge Center, Minn	70	6.90
3	Mallory, Cushing & Co., Omaha, Nebr	70	6.75
4	Albert L. Love, Livingston, Mont	70	*5.10

* Accepted.

REPORT OF LIEUT. W. E. CRAIGHILL, CORPS OF ENGINEERS, ON SURVEY IN YELLOWSTONE PARK, OCTOBER AND NOVEMBER, 1890.

The party as finally organized consisted, besides myself, of the following:

Transitman	1
Leveler	1
Rodman	1
Chainmen	2
Flagman	1
Axmen	2
Cook	1
Second cook	1
Packers	3
Guide and packer	1

The transportation while we were away from the wagon roads consisted of 20 head of horses, of which 12 carried packs. After reaching the end of the road on Yellowstone Lake 2 four-mule teams with wagons were substituted for the packs.

The instrumental work of the survey was begun on the 13th of October, at Old Faithful Geyser. From this point the line was run up the Firehole River by the south shore of Shoshone Lake to Yellowstone Lake, thence to the outlet of Yellowstone Lake and down the Yellowstone River to Inspiration Point. The total distance was 63.91 miles. We were much delayed by the weather, which was continually stormy during the first two weeks. The snow by this time had accumulated to a depth of 18 inches or more, and not only were the labor and discomforts of the party very much increased thereby, but it was also a matter of doubt whether the horses could keep alive when the grass was so thickly covered with snow. From October 19 to November 5 the weather was clear and comparatively warm, but the snow on the ground made walking very hard until October 31, when we reached the west end of Yellowstone Lake. From November 5 to November 17 when the transit work was completed, snow fell nearly every day and the weather was cold, probably 15° below zero at times. The party was not sufficiently strong in the lower ranks. In the heavy timber the entire transit party was often delayed because there were so few axmen, and in the timber the level party could have gotten along faster if an axman had been attached to it. As the speed of the survey was determined by the rate of the level, an axman at this point would probably more than have saved his wages. An extra man or two would have decidedly improved the *morale* of the party, because I would then have been able to discharge disaffected ones without crippling the party.

We had with us 1 transit and 1 level only. There should have been 2 of each to provide for accidents. The country passed over was extremely rough, and the snow on the ground made constant falls unavoidable. The transit was broken once and its tripod once, and we were fortunate in being able to repair the injuries sufficiently well to continue the work. The leveling rod was of the target variety. A self-reading one would have expedited the work.

The method of work pursued was similar to that used in railroad work. Stakes were driven at 100 feet distance apart and numbered consecutively from the beginning, and the number written on the stake. The angle of the first course with the magnetic meridian was read, and afterwards, at each point of change of direction, the angle to the right or left was read. The compass was read occasionally as a check. Levels were taken at every station and at intermediate points of interest. Where the slope across the line was greater than 1 in 20 the level of points 9 feet (half the width of the roadway) on either side of the line was taken. Bench marks were established, generally on a convenient tree, at intervals of about 1,000 feet.

They were marked U. S. B. M., and the elevation of each above the assumed datum was written on it.

Throughout it was necessary to sacrifice somewhat the accuracy that might have been desirable for fear of being driven in by snow before the line was completed. The accompanying map and profile show the route passed over and the details of the proposed road. From station 0 to station 182, 3.4 miles, the line follows the road already partly completed. From station 182 to station 344, 3.1 miles, the line follows the course of the Firehole River. It lies generally through timber and the construction of the road will present no difficulties, as in this section there will be but little cutting or side-hill work. From station 344 to station 384, 0.8 mile, the line, having left the Firehole, follows the bed of one of its tributaries towards the summit of Grant Pass, in the Continental Divide. In this section the work will be continuously side-hill cutting, the line crossing the stream repeatedly. This stream is, however, insignificant, and can easily be carried in the ditches of the road. From station 380 to station 451, 1.3 miles, the line passes through Grant Pass. This pass is flat and quite smooth, so that the principal work of building the road will be in removing the timber and finishing. From station 451 to station 477, 0.5 mile, the line runs through an open meadow and presents no difficulties. Beyond this meadow it was a question whether to follow Shoshone Creek to Shoshone Lake or to go down the ridge between Shoshone Creek and the creek next to the southward. A trial line was partly run over the latter route, but was afterwards abandoned, because the ridge was found to be extremely rough and broken, necessitating a summit higher than that in Grant Pass of the Continental Divide, and the descent into Shoshone Geyser Basin would be sharp and long. For these reasons the alternate route by Shoshone Creek was taken. The objections to it are that in its upper part the sides of the cañon of the creek are rather steep, necessitating considerable side-hill cutting, and in its lower part the bed of the creek is a great swamp. From station 477 to station 581, 2 miles, the line follows this creek. For the first part of this distance, or from station 477 to station 525, the cañon of the creek is narrow and crooked, but its sides are earth slopes and present little difficulty. From station 525, however, the bottom widens out into a swamp through which the stream makes its way in a tortuous course, winding from side to side in such a way that the only choice was between crossing it repeatedly and cutting the road into the sidehills. The latter course was objectionable because the sidehills are full of springs, and for a considerable distance are more swampy than the bottom itself. This bottom swamp extends from station 525 to station 550, 0.5 mile. It is covered throughout with grass and trees, and I think has a foundation of hard gravel about 2 or 3 feet from the surface. The bed of the creek is hard and made up of small angular fragments of volcanic rocks. The condition of the swamp can, I think, be improved to such an extent by drainage and perhaps by cutting off some of the bends in the creek so as to increase its slope, that the construction of the road will not present as much difficulty as might at first seem. From station 564 to station 592 the line passes through the Shoshone Geyser Basin. The soil is geyser "formation" and will have to be well covered with clay hauled from the sidehills. From station 592 to station 612 + 8, 1,938 feet, the line crosses a swamp, which will have to be bridged or else filled for the roadbed. The bottom of the swamp seems to be hard, but it is subject to overflow from the lake. From station 612 + 8 to station 652 + 80, 0.75 mile, the land follows the beach thrown up between the lake and the marsh. This beach is of gravel and sand, and has a sufficient width above high-water mark for the roadbed. Clay will have to be hauled from either end for covering. From station 652 + 80 to station 747, 1.5 miles, the line follows closely the shore of the lake, the intention being to build the road partly in the water, excavating the necessary material from the sidehill, which is here steep. The bottom of the lake slopes very gradually and is hard, formed of angular volcanic gravel. Along this part it seems to be not much exposed to storms. The lake level seems not to be subject to much fluctuation, the difference between high and low water being not over 1 foot, I should judge from the indications on the shore. From station 747 I started a trial line, intending to follow farther the lake shore, but this was abandoned and the line taken by the shorter cut over the hill to the mouth of Moose Creek. For one-half mile or more at the point where the lake is narrowest, the south shore is a ledge of solid rock rising nearly vertical from the water, and at times even overhanging. This shore is evidently subject to quite severe gales, which would render it difficult to maintain a roadway built at the water's edge. A saving in distance estimated at 0.75 mile was made by going over the hill. From station 747 to station 918 + 64, 3.3 miles, is occupied by this crossing to the valley of Moose Creek. The ascent to the top of this divide is made in the bed of a little creek which at the time of the survey was completely dry. There will be but little side-hill work. From station 839 to station 858, 1,900 feet, is on the top of the hill and very flat. The principal work will be in removing the timber. From station 858 to station 918 + 64, 6,064 feet, being the descent of the Moose Creek side, the work is more difficult, being generally on the side hill. There are some indica-

tions of rock under the surface, but there was so much snow on the ground that this was a question that could not well be determined. From station 918 + 64 to station 928 + 91, 1,027 feet, is the crossing of the swamp at the mouth of Moose Creek. This will either have to be on a bridge or a fill. Moose Creek will have to be crossed by a bridge about 50 feet long. The swamp is very soft and deep, and with much quicksand. It is flooded by the backwater from beaver dams in the creek. From station 928 + 91 to station 963, 0.6 mile, the line follows the beach thrown up between the lake and the swamp. It is similar in its nature to the one at the west end of the lake. From station 963 to station 1002, 0.7 mile, the line ascends to and follows the beach above the lake shore. From station 1002 to station 1020, 1,800 feet, it is again at the water level. The bottom is similar to that already described. From station 1020 to station 1440, 7.9 miles, after crossing Lewis River, the line passes through most favorable country, the most of it being not timbered. The ascent to the top of the divide is made in the valley of a little creek which is dry except in the spring. Its valley is flat, and there will be little to be done beyond ditching and finishing. From station 1190 to station 1440, 4.7 miles, *i. e.*, from the top of the divide to the Warm Spring Camp, the location is favorable, although not so good as that on the Shoshone side of the divide. The creek down which the course lays was dry in its upper part at the time of the survey. From the Warm Spring Camp to Bluff Point (from station 1440 to station 1587, 2.75 miles) the line follows closely the shore of the lake, the locations being on the bench about 15 or 20 feet above the level of the lake. The soil, except where it is spring deposit, is like that on the shore of Shoshone Lake, having more clay in it than that nearer the outlet of Yellowstone Lake. The character of the gravel is different also, being made up generally of angular fragments of porous volcanic rock. At Bluff Point (between stations 1587 and 1615, 0.5 mile) there is a section of heavy side-hill work. From station 1615 to station 1672, 1.1 miles, the line is again on the level bench. From station 1672 to station 1790, 2.1 miles, it is on the beach of the lake which, except to station 1706, 0.6 mile, is a sand and gravel ridge thrown up by the waves, and having a smaller lake or lagoon on its inner side. It will be necessary to haul clay for its covering. The rest of this section, 1.6 miles, is at high-water mark on the beach, which is at the foot of a slope of sand. This sand is so loose that in order to form the roadbed it will be simply necessary to scrape material from the bottom. That above will continually roll down. Wherever the road is near the lake level its outer edge should be well protected by riprap to preserve it from the violence of the waves. From station 1790 to station 2071, 5.3 miles, the line is on the bench that forms the lake shore, but little will be required for its construction beyond the clearing away of the timber, but ditching and finishing. From station 2071 to station 2425, 6.8 miles, the line follows the partly completed road. From the Lake Hotel to Mud Geyser (from station 2425 to station 2802 + 52, 7.1 miles) it follows the course of the river quite closely, except where a saving in distance could be effected in the bends. At the Mud Geyser (from station 2802 + 52 to station 2827) there is a short section of about 0.5 mile of heavy side-hill work, the excavation of which will be partly in rock and spring deposit. In passing through Hayden Valley (from station 2827 to station 3108, 5.3 miles) the line follows the river. A large portion of this is side-hill work, but the soil will be easy to work and there is no timber. Some corduroy will be needed for the swamp near the southern end, but fortunately it is not far from this point to the timber on the hills. From station 3108 to station 3143, 0.7 mile, the line is near the river's edge at the foot of the bank, which is bluff. From station 3143 to station 3190, 0.9 mile, the line comes again to favorable country. From station 3190 to station 3243, 1 mile to the old hotel site, it follows the old roadway except for a few hundred feet near the hotel. It was at first my idea that this portion of the line should follow the course of the river so as to give a view of the Upper Falls and of the rapids, but after a closer examination, I concluded on account of the great difficulties of this location that it would be better for the present to continue to use the old road, which is also shorter. It is not more than 200 yards from the old hotel site to the Upper Falls, and from the nature of the ground a road could be opened there at a very small cost. This would give access for vehicles to the Upper Falls and Rapids. From station 3243 to station 3287 + 24, 0.7 mile, the line follows the completed road. At station 3287 + 24 it leaves it again, turning off towards Inspiration Point (3380). The length of new road to be built here is 1.8 miles.

GRADIENTS.

The survey was carried over the completed roads on the Firehole and that near the Grand Cañon partly in order to determine with some degree of accuracy what are the gradients we may allow in our work. At both these points there are hills which are sufficient to give the desired information. The one on the Firehole, near Kepler Cascade, gives examples of such grades as it is desirable should not be exceeded. On the main part of the hill the gradient is about 7¼ per cent and this is

eased off towards the top to 4 per cent and finally to an even gentler slope. At intermediate points on the steeper part there are also short lengths of a gentler slope. These are, I think, important where practicable, as affording intervals of relief for the horses. It is also important to make the slopes on the curves very gentle, as at these points the teams, especially long freight trams, can not exert their strength so well as on a straight portion of the road. For this reason, also, it is better, where possible, to make the hill perfectly straight. On the Grand Cañon Hill the circumstances made it impossible to keep the gradient as low as is best, and for 900 feet it is 9¼ per cent. This is as steep as should be allowed on long grades, and in order that the horses may not have to pull so hard at the top of the hill where they will be tired, the steep part should be followed by a lesser grade. This is illustrated in the Grand Cañon Hill. The gradients from the bottom to the top are as follows:

	Per cent.
For 900 feet gradient	9.33
For 1,300 feet gradient	4.6
For 950 feet gradient	1.6

For short pulls not exceeding 100 or 200 feet the gradient may be as high a 10 per cent.

My conclusions are, therefore, as follows:

Wherever the ground will permit and the cost is not excessive a grade of 7½ per cent should not be exceeded. Where, for exceptional reasons, this is not practicable, the grade should not exceed 9 per cent for long hills, and for short ones of not more than 100 or 200 feet 10 per cent may be allowed. Within these limits the natural surface of the country may be followed.

Respectfully submitted,

W. E. CRAIGHILL,
First Lieut. Engineers.

APPENDIX H H H.

EXPLORATIONS AND SURVEYS IN DIVISIONS AND DEPARTMENTS.

H H H 1.

EXPLORATIONS AND SURVEYS IN THE DIVISION OF THE MISSOURI.

ANNUAL REPORT OF CAPTAIN WILLIAM L. MARSHALL, CORPS OF ENGINEERS, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

HEADQUARTERS DIVISION OF THE MISSOURI,
Engineer Office, July 1, 1891.

GENERAL: I have the honor to submit my annual report as engineer officer, Division of the Missouri, for the fiscal year ending June 30, 1891:

The office force has consisted of one general service clerk, Frederick A. Peterson.

There has been no field work in progress during the year.

The office work has consisted in collecting, compiling, and plotting geographical information for the improvement of existing maps, in making reductions and enlargements and facsimile copies and tracings of maps of military and Indian reservations, posts, scouts, reconnoissances, for use at these headquarters and elsewhere in the division, for file and forwarding.

During the year the engineer officers of the departments included in this division have forwarded such special reports and maps of work done as were useful to the major-general commanding the division, as well as to the other officers connected with these headquarters.

LIST OF MAPS AND TRACINGS DRAWN.

Tracing of Fort Riley military reservation, Kansas, resurveyed by Lieutenant Chittenden, Corps of Engineers, April, 1890.

Tracing of a sketch road from Fort Meade, S. Dak., to camp on Cheyenne River, Captain Hennissee, Eighth Cavalry, commanding.

Two tracings of map showing the "Division of the Missouri," with commanding officer and troops stationed at each post; also camp of troops in South Dakota and vicinity during the Indian campaign, 1890-'91.

Tracing of Mammoth Hot Springs, Yellowstone National Park, showing proposed site for new post.

Tracing of map showing scene of fight on Wounded Knee Creek, South Dakota, December 29, 1890.

Tracing of map showing scene of fight at the Mission near Pine Ridge Agency, South Dakota, December 30, 1890.

Map and two tracings of "country showing the different positions of the troops during the Indian campaign in South Dakota during November, December, 1890, January, 1891."

Map and tracing of "route of Capt. F. D. Baldwin, Fifth Infantry, from Fort Davis, Tex., and return," December, 1888, and January, 1889.

Tracing of Fort Assiniboine military reservation as described in General Orders No. 28, A. G. O., 1888, showing the proposed reduction of the reservation.

Maps received and issued:

Title of maps.	On hand June 30, 1890.	Received during 1890-'91.	Issued.
United States, showing military posts, departments and divisions	5	6	3
Territory of the United States, west of the Mississippi River	8	12	9
Map of country comprising Forts Meade, Custer, Keogh, and McKinney, etc		11	4
Map of country surrounding Pine Ridge and Rosebud Indian agencies, etc		17	6
Map of the Sioux Indian Reservations in North and South Dakota and adjacent territory		3	2

Made seven blue prints of maps showing "the Division of the Missouri," with commanding officer and troops stationed at each post, etc., etc.

Made fourteen blue prints of map showing different positions of troops during Indian campaign in South Dakota, November, and December, [1890,] and January, 1891.

Made twenty blue prints of map of fight on Wounded Knee Creek, December 29, 1890.

Made twenty blue prints of map of fight at the Mission near Pine Ridge Agency, December 30, 1890.

Made eight blue prints of map of route of Camp F, Fifth Infantry, October 11 to December 7, 1890, Capt. F. D. Baldwin, Fifth Infantry.

Made three blue prints of "route of Capt. F. D. Baldwin, Fifth Infantry, from Fort Davis, Texas, and return, December, 1888, and January, 1889."

Mounted seven maps on linen.

Respectfully submitted.

W. L. MARSHALL,
Captain, Corps of Engineers,
Engineer Officer, Division Missouri.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. Army.

H H H 2.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF THE COLUMBIA.

REPORT OF CAPTAIN CHARLES H. CLARK, ORDNANCE DEPARTMENT, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

ENGINEER OFFICE,
HEADQUARTERS DEPARTMENT OF THE COLUMBIA,
Vancouver Barracks, Wash., July 1, 1891.

SIR: I have the honor to submit the following report as acting chief engineer, Department of the Columbia, for the fiscal year ending June 30, 1891.

This office was in charge of Maj. G. J. Lydecker, Corps of Engineers, until May 13, 1891, when he was relieved by operation of paragraph 3, Special Orders No. 80, Headquarters of the Army, dated April 16, 1891. The undersigned was then directed by the department commander to take charge of the office temporarily.

FIELD OPERATIONS.

The field operations during the year have been as follows:

1. Surveys of roads in the military reservation of Vancouver Barracks, Wash.
2. Resurvey of the boundaries of the Boisé Barracks military reservation. (Left Vancouver Barracks October 23, returned November 5.)
3. Minor surveys rendered necessary by changes and improvements on the Vancouver Barracks military reservation.

OFFICE WORK.

The office work has included the preparation of maps and reports based on the surveys referred to above, the addition to the progress sheets of the department map of all new information as received from time to time, various reports in relation to matters referred to this office for information and action, and miscellaneous work, as follows:

Department maps issued	22
Map and plans drawn by hand	14
Tracings for issue and office	21
Solar prints	214
Negatives for official use	8
Maps mounted on linen	16
Reports of scouts received and recorded	13

PERSONNEL.

General Service Clerk Charles A. Homan was in this office as assistant from the date of last report until September 12, 1890. General Service Clerk Napoléon de Grace Dion was then assigned to this office, and has remained since that time. There has been no other office force.

No funds have been available for use in this office during the year. Stationery and such other materials as were imperatively necessary for carrying on the operations of the office were supplied, as usual, by the Quartermaster Department.

Very respectfully, your obedient servant,

CHARLES H. CLARK,
Capt. of Ordnance Dept.,
In charge of office.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

H H H 3.

EXPLORATIONS AND SURVEYS IN THE DEPARTMENT OF THE PLATTE.

REPORT OF LIEUTENANT CHARLES A. WORDEN, SEVENTH INFANTRY, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

ENGINEER OFFICE,
HEADQUARTERS DEPARTMENT OF THE PLATTE,
Omaha, Nebr., July 1, 1891.

SIR: I have the honor to submit my annual report as acting engineer officer of the Department of the Platte for the fiscal year ending June 30, 1891.

The work performed in this office during the year has been principally map compilation. The following named maps have been prepared:

"Map of the Pine Ridge and Rosebud Indian Reservations and surrounding country." This map is projected on a scale of 1:1,000,000, and embraces the territory surrounding the Pine Ridge Indian Agency for a radius of nearly 200 miles. It was compiled from the best obtainable data for the use of the troops engaged in the recent Indian campaign in South Dakota, and has been corrected from time to time so as to be as complete and reliable as its scale will permit.

Another map of the country surrounding the Pine Pidge and Rosebud Indian agencies, on a scale of 8 miles to an inch, showing more details than the former map, has been compiled from numerous maps, sketches, reports, etc., of officers and scouts engaged in the campaign.

Two hundred and twelve blue print copies of these maps have been made and distributed to the officers in this and other military departments requesting them.

About thirty maps of the Department of the Platte and adjacent territory west of the 103d meridian have been issued on request, besides numerous other maps, tracings, blue prints, etc.

By direction of the department commander a map of that portion of this department east of the one hundred and third meridian, which will include the States of Iowa, Nebraska, South Dakota, Kansas, and portions of Missouri, Minnesota Wisconsin, and Illinois, was commenced last fall. This map is projected so as to join the map of the western portion of this department already published, thus making one map of the entire department with adjacent territory. Numerous county maps have been received from the county surveyors in Iowa, Nebraska, and South Dakota for use in the compilation of the above-named map, and it is expected to be completed for publication before the end of the next fiscal year.

Drawing supplies for this office have been received from the Quartermaster's Department.

Engineering instruments, note books, etc., have been issued on memorandum receipts to the various posts in this department whenever requested.

Very respectfully, your obedient servant,

CHAS. A. WORDEN,
First Lieutenant, Seventh Infantry,
Acting Engineer Officer.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

H H H 4.

EXPLORATIONS AND SURVEYS IN THE DIVISION OF THE PACIFIC.

ANNUAL REPORT OF LIEUTENANT JAMES E. RUNCIE, FIRST ARTILLERY, FOR THE FISCAL YEAR ENDING JUNE 30, 1891.

ENGINEER OFFICE,
HEADQUARTERS DIVISION OF THE PACIFIC,
San Francisco, Cal., June 30, 1891.

SIR: I have the honor to submit my report of operations for the fiscal year ending June 30, 1891.

Since rendering my report for the last fiscal year (1890) I have been on duty at these headquarters as acting engineer officer, under authority of the Secretary of War, and by virtue of General Orders No. 2, dated Headquarters, Division of the Pacific, March 3, 1888.

Assistant C. Winstanley has been continually on duty in this office as topographer and draftsman. Owing to the fact that he has been assigned to duty as assistant to the division inspector of artillery, very little has been accomplished in the way of office work, which has consisted of the following:

ORIGINAL DRAWINGS.

Drawings for hospital steward's quarters for Fort Mason, Cal.

Diagram showing the position of troops at the funeral of the King of the Hawaiian Islands.

Colored maps of the Departments of California and the Columbia for the division commander.

TRACINGS.

Drawings for hospital steward's quarters at Fort Mason, Cal.

Map of portions of Tulare, Inyo, and Fresno counties, Cal.

Map of the part of the city of San Francisco referred to in H. R. 7522, United States Senate.

Diagram showing the position of troops at the funeral of the King of the Hawaiian Islands.

Map of San Diego Bay, showing the proposed defenses.

BLUE PRINTS.

Drawings for hospital steward's quarters at Fort Mason, Cal., 6 sheets.

Map of portions of Tulare, Inyo, and Fresno counties, Cal., 8 sheets.

Diagram of the position of troops at the funeral of the King of the Hawaiian Islands, 7 sheets.

Two maps of San Diego Bay, showing proposed defenses, 2 sheets.

MAP MOUNTING.

Map of the Department of California, for the division commander, 1 sheet; map of the Department of California, for the assistant adjutant-general, 1 sheet; two maps of the Department of the Missouri, 8 sheets; two maps of the Department of Dakota, 2 sheets; map of the Depart-

ment of California, in book form, 1 sheet; four maps, geological survey of the State of California, 16 sheets; map of Yosemite Valley, 1 sheet; three maps of Yosemite National Park, 3 sheets; Land Office map of the State of California, 2 sheets; repaired and remounted map for the chief quartermaster of the division.

Very respectfully, your obedient servant,

J. E. RUNCIE,
First Lieut., First Artillery, Acting Engineer Officer.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. Army.

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